UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF NORTH CAROLINA
ASHEVILLE DIVISION

STATE OF NORTH CAROLINA ex rel. Roy Cooper, Attorney General,	)	
Plaintiff,	)	No. 1:06-CV-20
vs.	)	VOLUME 10B
	)	PAGES 2467-2593
TENNESSEE VALLEY AUTHORITY,	)	
Defendant.	)	

TRANSCRIPT OF TRIAL PROCEEDINGS
BEFORE THE HONORABLE LACY H. THORNBURG
UNITED STATES DISTRICT COURT JUDGE
JULY 25, 2008

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I N D E X

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E X H I B I T S

DEFENDANT'S EXHIBITS:

NO.	DESCRIPTION	MARKED	RECEIVED
410	Grigal report	2555	2557
411	Grigal supplemental report	2556	2557
412	Grigal CV	2543	2557
413	Titration chart	2578	2580
414	Historical graph	2566	2575
415	Acidic deposition chart	2575	2577
420	Tombach report	2470	2487
421	Tombach supplemental report	2470	2487
428	Graph-conclusion #1	2509	2514
429	Graph	2513	2514
430	Chart	2517	2518
431	Graph	2521	2525
432	CMAQ modeled, 24-hr impacts	2519	2525
433	Visibility impacts, 2013	2527	2528

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P R O C E E D I N G S

THE COURT: All right. Call the next witness.

MS. GILLEN: Tennessee Valley Authority calls Dr. Ivar Tombach to the stand.

If I can suggest the witness take from that stand, TVA Exhibit Notebook Number 18. Then we will have occasion to refer to one Plaintiff's Exhibit which is in Plaintiff's Exhibit Book Number 6.

THEREUPON, IVAR TOMBACH, being first duly sworn, testified as follows during DIRECT EXAMINATION BY MS. GILLEN:

Q. Good afternoon, Dr. Tombach.
A. Good afternoon.
Q. Could you please state your full name for the record?
A. Yes. My name is Ivar Harold Tombach.
Q. And where do you live?
A. I live in Camarillo, California, southern California.
Q. And what is your current employment?
A. I'm an independent, self-employed consultant.
Q. And what areas do you provide consultation in?
A. Air pollution, principally, particulate matter and visibility and things related to it.
Q. And were you asked by TVA in this case to develop some opinions?
A. Yes I was.
Q. And what did TVA ask you to opine on?

A. They asked me to look at the visibility consequences of the various emission scenarios that have been modeled, and particularly in 2013, to look at how large the visibility impact of emissions under the TVA plan would be in North Carolina at the requested areas of the current nonattainment counties.

And also what the differences in visibility would be -- what the differences in visibility would be if, instead of the TVA plan, the Clean Smokestacks equivalent plan were adopted.

Q. And are the opinions you formed on those questions contained in reports that you submitted?

A. Yes they are.

Q. And if you would be so kind to turn to what has been marked for identification as Defendant's Exhibit 420 in your book.

A. Okay.

Q. Is that your first expert report?

A. Yes, it is.

Q. And if you would turn to what has been marked as Defendant's Exhibit 421. Is that your supplemental expert report?

A. Yes, it is.

Q. And for reference, if you'd like, at the back of Defendant's Exhibit 420 A-1 is a copy of your resume, I

believe.
A. That's right.
Q. Let me know when you got there.
A. I found it.
Q. Dr. Tombach, please tell us where you received your education.
A. I received a Bachelor degree in engineering with honor from the California Institute of Technology, Cal Tech.
Then I went to Cornell University and received a Masters degree in aerospace engineering. And then returned to Cal Tech, where I obtained a Ph.D in aeronautics, with specialization being on mixes of turbulent gases.
Q. And if you turn to -- if you would please, Ms. Shay, display on the screen, for ease of use, page A-3.
I would like to ask you what you did after you completed your doctorate.
A. When I completed my doctorate in 1969, I went to work at a company called Meteorology Research. And there, my responsibility was to provide scientific support for various meteorological instruments and visibility-measuring instruments the company manufactured.
In fact, my first assignment when I got there was to take one of their instruments, called an integrating nephelometer, a term I think you heard before, out to New Mexico and to survey the effects of the emissions from the

coal-burning Four Corners power plant on visibility in areas of New Mexico. That was back in 1969.

Q. Would you just spell "nephelometer" for Madam Court Reporter.

A. I'm sorry, I didn't hear that.

Q. Would you spell "nephelometer"?

A. Sure. N-E-P-H-E-L-O-M-E-T-E-R.

Q. And then, for the rest of us, would you explain what a nephelometer is.

A. Sure. It's an instrument that takes a sample of air and basically shines light on it, and, from that, it determines the properties of the air in scattering light. Which is what affects visibility in the atmosphere. So it simulates the scattering that you see with your eye.

Q. And what did you do after your work at Meteorology Research, Incorporated?

A. Well, I worked there two years, and then three of us started our own consulting firm, a company called AeroVironment, A-E-R-O-V-I-R-O-M-E-N-T. I headed the Environmental Division of the company for the next 19 and a half years, which was 140 people, involving measurements and modeling and analysis of air pollution issues. And then I left them in 1991.

Q. To do what? What did you leave in 1992 to do?

A. I'm sorry. Again?

Q. What did you do when you left AeroVironment?
A. Okay. Well, then I had been in one place for 20 years and didn't really know what to do with myself. So I took a period of time to figure out my future. And to keep bread on the table, I continued doing consulting work, which is something I'm familiar with.
So I did that for a year, until I got an offer I couldn't refuse from a company called ENSR, E-N-S-R, in Camarillo, California. So I moved to California and became a Vice President of ENSR and a National Program Manager for them.
Q. And you're not at ENSR now?
A. No. I was in ENSR for seven some odd years, and left them the beginning of 1999, and became an independent environmental consultant again, and have been so for the last 10 years now.
Q. Who have been some of your clients in your independent consultant work?
A. It runs the spectrum from government to industry to various kinds of groups and such.
I notice that the SAMI has been the topic of discussion for a while. SAMI was one of my clients. I did peer reviews for them when completing their report, reviewed their modeling work and visibility analysis.
Another client had been the National Park Service.

They, for example, paid for my work on writing a final report for the BRAVO Study. Which I think we will get to in a minute in more detail. I've done work for EPA.

In the past, before I became an independent consultant, I managed some very large field studies for them, and not on management, but was principal director of.

But in my one-man situation, I have done peer reviews for them of the REMSAD model, for example. And peer reviews of grant applications that they have received an award of grants to, universities and such.

Q. What is REMSAD model?

A. REMSAD model is a simplified air pollution model, very much like the CMAQ model that we will be talking about, or CMAx model, except it is simplified. It evolved from the aerosol model and ozone model. And it was an attempt to model air pollution issues, such as visibility, with something that would fit the computing capabilities that were around 10 years ago. I think it pretty much dropped out of favor since then.

Q. I'm sorry I interrupted you. Are there any other representative clients?

A. Well, okay. Then -- so I have a done fair amount of work for the Electric Power Research Institute. Before I became a one-man consulting firm, there were a number of major programs that I carried out for EPRI.

And then, since I went off on my own, I have done seven or eight small projects for writing reports for them, doing research, paper kind of research, things of that sort.

I -- a major client of mine in the last six years has been SESARM, Southeastern States Air Resource Managers. And they hired me to be the technical adviser to VISTAS.

VISTAS is the regional planning organization for regional haze advisory for southeastern United States. That represents 11 southeastern United States.

And that's a function I'm still carrying out at the moment right now. And then, of course, a client TVA, as an example. Since I'm here on behalf of TVA.

Q. Have you been published in the field of visibility? And if you would like, I think a list of your publications begins on page 84 of your resume.

A. Yes. The resume lists about 30 peer-reviewed publications in visibility. And all, in total, I've probably done over 150 reports and conference papers and peer review papers on visibility. I've done 50 of them in the last 10 years.

Q. And I'll just pick out a couple that maybe you can highlight for us. The first one on your list, the Tombach and Brewer, 2005, what did that address?

A. Right. The title of it is Natural Background Visibility and Regional Haze Goals in the Southeastern

United States.

That's a paper I prepared with the support of VISTAS. And in fact Pat Brewer is the technical coordinator for VISTAS.

And the regional haze rule describes that the goal is to try to reach, by year 2064, natural conditions in visibility in the Class One areas.

So the question is, what are natural conditions, since we don't have any.

And so this paper addresses what factors affect the rest of areas of natural conditions, and makes an effort to figure out what they might be in the southeastern United States.

Q. And on the next page A-5, what is Zannetti, Tombach -- and I can't pronounce the third -- Cveneck, 1993, *Calculation of Visual Range of Improvements for SO2 Emissions Controls*?

A. This is actually a second of two papers; that's why it's got a Roman numeral two in the title.

The first paper, a little further down, called *Zannetti and Tombach 1990.* Let me start with the 1990 one because the 1993 builds on it.

The 1990 one was an evaluation of various techniques for simulating visibility improvements from SO2 emission controls in the eastern United States.

The techniques we were interested in were ones that did not involve massive computing effort.

You have to understand, back in 1990, computers were a lot slower than they are nowadays. And to attempt to run a model like CMAQ then, which was totally out of the question, and even if you could run something similar, it took weeks to months to run a simulation. It was incredible.

This was looking at simplified methods of estimating ways of figuring out how much benefit you get from SO2 emission controls in the eastern United States.

Then the following paper, the 1993 one, the one you asked about, we actually applied that technology to some data, to indicate what kind of results we were obtaining from, for example, the acid rain controls.

Q. And just moving a little further down, is *Zannetti, Tombach and Cveneck, 1989, An Analysis of Visual Range*.

A. That was a precursor to the other two. Before we could do work in the eastern United States, we had to understand how visibility there varied, how it related to meteorology.

So this paper looked at visibility in the eastern United States in terms of meteorological regimes.

For example, polar air coming from the north, humid tropical air coming from the Caribbean, things of that sort.

We took various areas of the east and, in each of them, described how the visibility was affected under each of the

various meteorological regimes. And this paper describes how it was done and what they came up with.

Q. And how about the last one on this page, the Tombach and Allard, 1983. Tombach and Allard, I think, is on the next page?

A. Yeah. That is a product of an eastern visibility study that I think I'll be getting to later.

But this paper describes the -- it compares methods for varying visibility. The study involved human observers looking at objects on the horizon and elsewhere; involved instruments measuring the properties of the air; involved instruments looking at objects, and as an instrument, measuring optical properties.

And we related all of those in this article and it compares how these are compared. And it gives, among other things, some of the first results on relationship between instrumental measurements of air pollution and human perception of visibility.

Q. And in fact, were you also the lead author on a chapter of NARSTO, the visibility chapter in a book that was from NARSTO?

A. Yes. That's an interstate study. NARSTO, N-A-R-S-T-O, once stood for North American Research Strategy for Tropospheric Ozone -- a mouthful. But then it expanded its charter to include other pollutants, and so they dropped the

explanation of the title and call themselves NARSTO now.

NARSTO is an organization that is jointly composed of people from the United States, from Canada and from Mexico. And the whole goal of the program is to coordinate efforts at improving air pollution in the three countries. And, since air pollution doesn't respect borders, also, each time you deal with your neighbor, it also helps you.

They have periodically put out major reviews. This particular report was called *Particulate Matter Science for Policy Makers.*

And what it tried to do was describe, in a way that would be useful to policy makers, the science behind our current understanding of particulate matter.

One chapter in that report on *visibility and radiated balance, a climate issue*. I was the principal author of that chapter.

The report -- the editors were from Environment Canada, from the USEPA, and the University of Minnesota. Those were the three principal editors.

And the report itself was peer-reviewed by the American National Academy of Sciences and counterparts in Canada and Mexico, and came to be published in the book by Cambridge University Press.

Q. Dr. Tombach, if you could give us a brief highlight of the various visibility projects that you've been a part of.

I think it is in reverse chronological order. We can start on what's marked page A-3 in your report, with the *Persistent Elevated Pollution Episodes*.

A. Sure. Let me start before that. I mentioned the pollution comparison study. That occurred in the late 1970s.

In the late 1970s, a major regional field program took place called SURE, Sulfate Regional Experiment, and that experiment was really the first demonstration that sulfates were the big air pollution problem in the eastern United States, and where they went and how they migrated and such.

One part of SURE, an adjunct to it, which was a visibility study, for which I was principal investigator, where we monitored this -- put instruments in Pennsylvania and in Ohio, and for a year, monitored visibility.

And I mentioned the various instruments just a few minutes ago, and then related those measurements to the air pollution measurements made by the SURE air pollution monitors. We had a SURE monitoring station nearby.

So that was, I would say the first really -- first study ever done that really linked, in a large scale, visibility impairment to regional air pollution, and specifically sulfate air pollution.

And then that led to the next study, which you mentioned, which is PEPE, P-E-P-E, which stands for

Persistent Elevated Pollutant Episodes.

And that was a USEPA sponsored study, multi-million dollar study. I was one of three principal investigators for the study. We had three companies jointly doing the study.

It was a large-scale field study that took place in the summer of 1980, where we had about 100 people out in the field, and a dozen aircraft, all in various locations. And we profiled, in great detail, the areas of the east where there were high sulfate concentrations. We called them hazy blobs.

Because, what happened, we were finding out from SURE and others that these sulfate concentrations build up with time and form a kind of a cloud, you could say, that covered multiple states. And then eventually a front would come through or something and wash it away, get clean again, and then you build them up again.

So the whole goal of PEPE was to quantify the process and understand it as to how sulfate buildup in the east occurred. That was the scientific study I took lead on on that issue.

Q. On the previous, page A-2, moving up chronologically, what is the regional air quality studies?

A. After this focus on the east, for a while my focus of the projects moved to the west. And the first one was a

large scale program sponsored by the Electric Power Research Institute that was called the Western Regional Air Quality Studies, WRAQS. And that involved measurements of air pollution and visibility, particulate matter, essentially all the same things that SURE had done, but in the western United States.

We had 11 stations in nine states and ran them for over a year, to understand, again, the western air pollution situation.

At that point the program morphed into a different design and became part of what's called SCENES, which was a multi-organizational air pollution study focusing on the Grand Canyon and how did pollutants get to the Grand Canyon, where did it come from, and how did it affect visibility.

So I became principle investigator of one component of SCENES. That went on for several years.

That, in turn, lead to another study -- there's a whole sequence of these -- that, in turn, lead to another study -- let me go back.

So one thing that started coming out of this was, there was a possibility that a major contributor to air pollution in the Grand Canyon was the Mohave Generating Station in Arizona, near Page, Arizona.

And so, in the late 1980s, I became principal investigator of yet another multi-million dollar called the

Mohave Generating Station -- I'm sorry. Navajo. When I said Mohave a minute ago, I meant Navajo. Navajo Visibility Generating Study. That was a very comprehensive detailed study, mainly in the winter, to understand what -- how that plant was contributing to haze in the Grand Canyon.

The upshot of this whole sequence of studies was that eventually the Navajo Generating Station agreed to install scrubbers and pollution control equipment above and beyond what they had before, and in fact have done so since the 1990s.

Q. And how about the Dallas-Metro Ft. Worth project?

A. I'll mention one more western one. I mentioned Mohave by mistake, now this time it is Mohave.

The Clean Air Act Amendments of 1990 specified that the EPA was to carry out a study looking at the effects of the Mohave Generating Station, which is at the southern end of Nevada, on visibility in the Grand Canyon.

I was investigator on that particular study, which was sponsored not only by the EPA, but the Park Service and substantial funds put in by Southern California Edison, the operator of the plant, and other organizations, Sulfuric Project and others.

I was co-author of the final report that described the synthesized results of the study, measurements and modeling study. And the upshot of that one was the Mohave station

was shut down a couple years ago. That station is now in moth balls.

Now, you were asking about the Dallas-Ft. Worth.

Now we are moving out of the desert southwest into another part of the country.

The Texas Utility, which ran power plants outside Dallas, had a need to demonstrate to the Texas regulatory authorities that its plants were not contributing to visibility impairment in Dallas itself.

And while I was a one-man consulting firm for that one year, they called on me and asked me to design a field study for them to answer that question, which I did.

And then when I moved over ENSR, about a year later we were awarded a contract to actually carry out the study. Again I was principal investigator.

That study involved extensive measurements of the contributions of power plants outside the city, about 50 kilometers and further outside, modeling studies to further evaluate impacts, and some perception studies, where we went out and used perception tools, that I will get into later in this discussion, and then made pictures, made pictures of the scenes -- these are now urban scenes, buildings -- and then came up with the conclusion as to what the likelihood was to the contribution of the plants.

We concluded that the impacts of the plants on

visibility in Dallas was either negligible, at most, subtle.

The Texas regulatory authorities accepted that conclusion and, in turn, exempted Texas Utilities from having to install some controls.

Q. And finally, VISTAS. You worked on VISTAS?

A. VISTAS, yes. VISTAS, I mentioned, is the regional planning organization for the southeast. I have been a jack of all trades for them.

I have written many reports on many subjects. I mentioned a paper on natural conditions. I wrote the protocols for modeling for them. I reviewed almost everything they've done. I critiqued what many other planning organizations have done. And, in general, have been a technical gad fly for VISTAS folks.

As I say, all of VISTAS is now a shadowing form of itself. EPA's cut off its funding. I'm still employed in that role. I have to finish this testimony, I have to finish a report for them.

Q. Dr. Tombach, are you certified in your field?

A. Yes. I'm certified as a qualified environmental professional, which is a certification that is awarded by a collection of professional societies for people who have demonstrated through experience, examinations and references and such, that they are capable practitioners of the art of environmental science.

Q. And do you belong to any professional membership organizations?

A. Yes. I belong to several. I belong to the Air and Waste Management Association, of which I'm elected a fellow member. And I'm co-founder of the Visibility Technical Committee of that association, since 1978, and have been president of that committee twice since then.

I'm a member of the American Association for Aerosol and Research. I'm a charter member of that organization, which started in 1980, and have been a member since then.

I'm a member of the American Geophysical Union. I'm a member of the American Society of Mechanical Engineers. I'm a member of the American Meteorological Society. And finally, I'm elected to membership in Honorary Scientific Society, Research Society of America.

MS. GILLEN: At this time, Your Honor, TVA proffers Dr. Ivar Tombach as an expert in atmospheric sciences, with specialized emphasis in atmospheric processes, the effects of air pollution and the role of particulate matter in visibility impairment.

THE COURT: All right. So allowed.

MS. GILLEN: At this time TVA would also like to move into evidence Dr. Tombach's expert reports, which are marked for identification as Defendant's Exhibit 420 and 421.

MS. LYNCH: Your Honor, we're aware of the Court's prior ruling, but we would like to note our objection for admission of expert reports in evidence.

THE COURT: The objection is made and overruled, and the Court admits 420 and 421. All right.

(Defendant's Exhibit Numbers 420 and 421 having been marked, were received in evidence.)

Q. (Ms. Gillen) Dr. Tombach, a few of plaintiff's witnesses have given us an overview of visibility, but it's been a few days, so I wonder if you could give us a little refresher course to get us back in the framework of visibility.

What is visibility?

A. There is sort of many meanings for it. Everyone kind of knows what it means. But we'll get a little more definitive purposes of it.

For specific purposes of it, the best definition of it is the ability to see color, form, texture, shadows, things of that, in whatever view you're looking at, see them clearly.

For scientists, they need to have something a little bit more concrete to hold on to. So for scientists there are multiple definitions of visibility. The one very often referred to is the distance you can see.

And the scientific term for that is visual range. And

that is defined as the distance at which a human observer who is able to discern a 2 percent contrast with his eye, is able to see a large black target against the horizon sky.

So it's got a lot of qualifiers, but that nails down one definition of visibility.

Q. And then a couple of terms, just to review, I think we heard before. What is extinction co-efficient?

A. The extinction co-efficient is a measure of how much energy in light is lost as it passes through the atmosphere; and so you have a number that is related to a distance.

For example, an extinction co-efficient of 0.012 per kilometer, means that 1.2 percent of the light energy passing through the atmosphere is lost as it goes through one kilometer of air.

Q. How about haze index?

A. The haze index is derived from the extinction co-efficient. It's basically just taking the logarithm of it.

And the reason for the rescaling is because once you go into logarithms, an equal step of logarithms is equal to a percentage change from one number to the next. That's a little parallel to how the human eye-brain works in response to changes.

Q. Does that feed into deciview?

A. Yeah. Deciview is the unit in which the haze index is

described.

What will be of particular interest to us here is changes in deciview, between one scenario and another scenario. How much is the difference? Frequently, we express that in deciviews, which, in essence, you consider as a percent.

The translation is really fairly simple. A one deciview change corresponds to 10 percent change in the extinction co-efficient.

Q. And what affects visibility?

A. Visibility in the atmosphere is influenced by the gases and particles through which it passes. The gases are in the air, scattering of light by air. That's why we have a blue sky.

Then we have particles. That's what we're most interested in for our discussion here.

Q. Are there different kinds of particles?

A. Yes. We classify the particles in different ways. Some particles are natural in origin, and some particles are manmade, coming from human activities, including emissions from combustion.

We classify them by chemical composition, which turns out to be quite useful. And in that case, we typically classify them as sulfates, nitrates, organics, elemental carbon, which is soot, and soil particles. Both in large

and small sizes. We view larger and smaller sizes differently. And then, finally, salt, sea salt.

Q. Can you also differentiate them by their size or their origin and source?

A. Yeah. There's two things here to bring up. One is that small particles in the PM 2.5 range, are the ones that are most effective at scattering light.

It turns out what you need in a particle is about the same size in the way it affects the light, and that turns out to be a half a micrometer of PM 2.5 for two and a half micrometers --

COURT REPORTER: I'm sorry, Doctor. Can you slow down.

THE WITNESS: Yeah. Sure.

COURT REPORTER: I need to move this closer.

THE WITNESS: Okay.

COURT REPORTER: I need you to speak louder and slower, please.

THE WITNESS: Okay. All right. I can do both.

COURT REPORTER: Thank you.

THE WITNESS: Where did I leave off?

COURT REPORTER: What was your name again?

THE WITNESS: All right. I will pick up with the answer from the beginning. All right.

So there are a couple of ways to look at particles

that affect visibility. One important characteristic is the size, smaller particles, particles that are in the category we call PM 2.5, are particularly effective at scattering light and so they are for predicting visibility.

The larger particles, particles that may be in the PM 10 range, but above PM 2.5, are not quite as effective, but a lot of soil is in that air. And dust storms, for example, reduce visibility. So it has to be considered.

But an important consideration for fine particles is where do they come from. And they arrive in two ways. One is, is particles that were emitted someplace in the form of particles.

And most of them don't come that way. Most of them start out as gases. They are emitted in whatever source is in the gas. The gas in the atmosphere condenses and, by other chemical mechanisms, become particle.

And those particles are called secondary particles. And sulfates, nitrates and organic particles are all overwhelming secondary particles, whether from natural sources or manmade sources.

Q. And we are interested here in mostly secondary particles; is that right?

A. When we're talking about sulfates from power plants, yes. Those are secondary particles. And nitrates from power plants also.

Q. And how do you, as a visibility scientist, determine the effect of secondary particles on visibility; do you use a formula?

A. Well, there are very detailed scientific deep methods for relating particles and their sizes and compositions to their effects on light. They are too cumbersome to use on a day-to-day basis. So an empirical formula has been developed which is known as IMPROVE formula. That's I-M-P-R-O-V-E, all in capitals, that relates particle concentrations to the extinction co-efficient.

And basically what it does is, it assigns to every kind of particle, for example sulfate particles, an efficiency. A term that says how effective sulfate particles are at scattering light and nitrates and all the other components, all added together to arrive at the total impact of those chemical components on real life extinction co-efficient.

And that's pretty much used nowadays in the United States in connection with the Regional Haze Program and activities of that sort.

Q. Dr. Tombach, I would like you to describe how human beings perceive visibility.

And with the Court's permission, we have a diagram to help Dr. Tombach to explain his testimony if he would like to move around.

THE COURT: All right.

Q. So Dr. Tombach, to the extent this helps explain how humans perceive visibility, can you describe for the Court?

A. Sure. This is a diagram we borrowed from a book called, "Introduction to Visibility" by Dr. William Malm from the park service. And it's a very good illustration of all the phenomenon we're talking about right now.

If you assume you are an observer, here it happens to be somebody hiking on a mountain top, and you're looking at another mountain top over here, what you're really seeing is the sunlight lights up the target, the mountain top, and that image of it is sent in your direction.

But that imagine has to pass through the atmosphere and the atmosphere alters. The particles that are in it, some of the particles in it take the light that's coming, send it off, scatter it in a different direction. Some particles stop the light, they absorb the light and actually convert it to heat, soot, as I said.

In addition, we have the sunlight itself gets -- shines on particles. Those particles sometimes scatter light back into the beam. So we end up getting extraneous light which wasn't part of the imagine coming towards us. And then we also have reflections from the ground that also contribute light and cause that.

So by the time we get an image here, it has been contaminated by stray light coming from elsewhere, and by

loss of signal because of the material in the way.

And so what we see at the end is impaired, compared to there, because of the intervening medium.

Now the degree of this change, or this degradation is effected by the four items that are listed in boxes in the corners. One very important item is the observer itself. What are the thresholds at which the observer can perceive different things happening. Everyone is different in that regard. We will talk about that later.

How does the eye/brain system respond to the incoming light. And how do you -- what's your values. For some people they would say a small amount of degradation is more important to them aesthetically than to another person. So you have value judgments.

We have optical characteristics of the illumination. We have sunlight. Sunlight comes through clouds so we have dark and light. Some areas are dark and some areas are light.

And it depends on where the sun is. Is the sun down low in the horizon. Is it shining towards you. Everyone knows if you're driving toward the sun in haze, you get a bright haze. If you're driving away from the sun at the exact same time you can see quite well. So the sun angle relative to you is important.

And in general, sky conditions of that sort.

We are -- the optical characteristics of the intervening aerosol are important. I talked about and reviewed sort of the issues involved there. The airlight that's coming in and contaminating the signal and the loss of signal from -- because of all the particles.

And the last item is, what are the optical characteristics of what you're looking at. How much of a contrast does it make with the surroundings; is it bright, is it dark, is it small, is it big.

All of these effect your perception of what you see and determine how well you can see it, or how well you can tell that things are changing.

Q. Dr. Tombach, we have also done a second blow up which is in back of you. And that's been marked for identification as Attachment 2 to Defendant's Exhibit 422. What does this show?

A. This shows -- illustrates one of the points I was talking about earlier about sun angle.

We have here a situation -- a picture taken from Canyonlands National Park, toward the east looking at LaSal Mountains, which is 30 kilometers away. I should mention, I'm also indebted to Dr. Malm for this picture.

And what they measured the air quality during a day as the sun moved across the sky, and it stayed constant. So the haze in all four pictures is identical.

They're in a strange order. We start out with the lower right-hand corner with the morning. In the morning, we have backlighting. The light is actually behind the mountain still, so everything is in shadow. Then we go to lower left, and the light gets up a little higher. And we see -- we start seeing some lightness to the structure, but we also start seeing some lightness to the sky. It's the glare in the haze phenomenon.

Then we go on to the upper right picture, that's getting around 10:00 in the morning. And now we begin to see some color. And you can tell by where the shadows are, kind of where the sun is.

And then as we get around noon, we see more color. And now the sun is shining down on the haze, and the haze looks less intense than it was when we were looking toward the sun and the haze.

So we have four pictures taken over a period of about six hours that show very different visual phenomenon for exactly the same scene under exactly the same air pollution.

Q. Thank you, Dr. Tombach. Did the extinction co-efficient and visual range measurements that we talked about, count for those psycho-physical characteristics of the observer?

A. No. The extinction co-efficient is simply a physical measurement of a piece of air. And it doesn't -- so it

counts for one of those four boxes in the discussion we just had. They do not take into account any of the other factors.

Q. And how do humans perceive a change in visibility?

A. Well, when visibility changes, we have to get clear what we're talking about here. And if we're -- I think what we want to focus on for this discussion is how does visibility change when the haze changes, not when the sun angle changes or things of that sort.

The way we detect change is by eye, by seeing how the color and the texture and the ability to see, this is where you can see it all change as the haze changes.

Q. Are all the responses to changes the same?

A. No. Human beings are as different as you can possibly be. So there are a wide variety of ranges, just as some can hear better than others, some can see better than others, some can smell better than others, it's the same thing. Our responses to changes are also very different.

Some people can detect a change much more readily than others.

Q. And can you just give us a walk-through of what the literature says about perceptibility thresholds for humans to perceive changes in visibility?

A. Sure. The whole question of visibility as a science, really developed with ships, and then later airplanes. And

that was the major focus for a long time. And then the military got interested in the last half of the last century, 1970 around thereabouts. And they started doing studies of how sensitive -- how small a difference an image could a human eye detect, or how sensitive was it to change what occurred.

They did it by putting monitors in front of observers and having patterns changed and they basically indicated when they detected changes and what they were.

That lead to models of human response to changes in images. And from that developed, eventually, some of the science was applied to scenic images, and attempts were made to determine what the human response would be.

Dr. Malm, in 1990, published a paper, or actually published part of a report for the National Acid Precipitation Program in which he presented his assessment that in a particular scene, a 5 percent change in extinction would be something that would be perceptible to the human being.

A few years later he came together with Dr. Mark Pitchford of the National Oceanic and Atmospheric Administration assigned to the EPA, and they developed the deciview scale we will be talking about. But they also made a judgment of what our sensitivity was to changes.

They said that they thought something between one and

two deciviews, using their new units, which would be between 10 and 20 percent change in extinction would be perceptible with a condition.

And the condition was, they thought that would be perceptible if the conditions of the scientific theory were met.

And one important condition is, whatever target you're looking at, is right at the visual range. It is the object that is actually on the horizon at exactly farthest distance you can see.

And if that is where the target is, then you should be able to tell 1 to 2 deciview change. That's a pretty strict requirement. You very often don't find something right exactly at the visual range.

And some follow-on research, and they allowed for that and said, if the distance is closer, it would require larger change in haze to be detectable.

That was elaborated on in much greater detail in a paper in 1999 by Dr. Willard Richards of Sonoma Technology, the same company Chinkin and Wheeler come from.

Where he pointed out that because most targets are not at the visible range. The perception threshold is considerably higher than one deciview.

And, in fact, you can show it proportional. If the target is at half the visual range, in other words, if you

can see 50 miles and see an object at 25 miles, it will take twice as much, 2 to 4 deciviews to detect the change, and so forth.

So as it gets closer, it will be even harder to tell there's a visibility change, and a change in the haze.

Well, their analysis was again based on the results of the theories that were developed based on people in video monitors.

Now, the fly in the ointment is that the human eye is much smarter than we think it is. It sees very differently in the real world than it does when it's seeing an image.

So if we're looking at -- some test patterns first of all are not a very good representation.

But secondly, even views of scenic views, scenic views, pictures on a television set or pictures there, pictures generated by WinHaze Model, are not a good representation of what the eye sees because there are a couple reasons.

This by the way is not new science. Over a hundred years ago scientific papers began to publish on this. Although it's become important because we're talking about scenic visibility.

And there are two phenomenon -- I'll throw out the words to impress you, one is called perceptual transparency. And the other is called color scission, S-C-I-S-S-I-O-N.

And what those two $64,000 words really are telling us,

is that the eye when looking through a haze, can tell what is the haze, and what is the object behind the haze, and can distinguish them separately. And for color, can tell the color of the haze separately from the color of the object behind the haze.

So this is something you can only do in the three dimensional world outside when you have the benefit of a full field of view.

If you try to do that with a picture, doesn't work.

There's an easy experiment you can do to convince yourself to convince you that I'm not making this up.

If you go outside at the next break, find yourself a hillside, got a little bit of haze hiding it. Then if you take your hands, make a small tunnel, quite small tunnel, small hole. Pick a dark spot or light spot, whatever you like. What you will see is blue or light gray, not the color of the spot. But through your hand you will see blue or gray, that's the haze. If you then take your hand away and look at the same spot, the whole thing will be green mountain top, green forest or brown earth, what have you.

So what we've done by making a little tunnel, we have taken away all the peripheral information from the eye. It can only see little bit. And from that little bit it concludes that it looks at haze.

But when we have the whole eye is open and see the

whole field of view, we can tell the difference between the haze and color behind it.

That's the phenomenon that calls into question the scientific work that's been done with video and artificial images.

Now, to try to quantify this, the effects of perceptual color transparency and color sission, there has been some research done, not very much. This is not exactly a major research, and the funding is not there. But most of the research has been done by Dr. Ronald Henry at the University of Southern California.

And he started out -- he did experiments starting in eighties. And in fact, he was involved in the Dallas-Ft. Worth study I described.

But of particular relevance, was an experiment he participated in, in the summer of 1995, right here in the Smoky Mountains called SEAVS, the Southeastern Aerosol Viability Study.

In SEAVS he did perceptible measurements using an instrument called a video fluor (phonetic) color indicator, in which an observer matched colors in his instrument with what they saw, as they looked at some object. And the colors changed, the perception changes as the haze changes.

And by determining how precisely you can match the colors, he was able to conclude when one could tell that

something had changed.

And he concluded from that experiment based on colors, that if you're looking at a very colorful object, you should be able to tell by 1.8 deciview change, if the object is at about one quarter of the visual range.

The most sensitive region in his analysis is about one quarter visual range. That's because the theory is different than what was in the Dr. Malm picture that I described earlier.

If the distance is not one quarter of the visual range, meaning if the object is closer or further away, or if it is not very colorful, than the threshold increases dramatically. It could be 4 or 5 deciviews before you could tell there was a difference in change.

So this study was followed by another one, also by Dr. Henry, using an improved instrument. This time he focused not on color, but on lightness. You can visualize the brightness. But in the optical world, lightness and bright, they mean difference.

And he was looking at the difference in lightness between features on landscape, you know, like a dark tree or a light soil, or things of that sort.

And in that particular study, he had many observers try to match the lightness of various things they saw. He concluded from that one -- that study, that at most,

something between 17 and 35 percent of the population would be able to see a change of one deciview.

Now, that is at most, because he concluded from an air analysis that he did, that his estimates were high. Probability estimates were going to be high. But -- so that's a range he comes up with.

So something -- depending on how strong the lightness, darkness contrast is, something between 17 and 35 percent of the population could see it.

If you go to larger changes, 2 deciviews, which is about actually 19 percent or so, you find that something around an average about half people can tell it's between 35 and 70 percent and higher changes.

By the time you get to 4 deciviews, virtually everybody can tell -- not everybody, but virtually everybody. And somebody need a bigger change in haze than 40 percent, 4 deciviews is about 35 percent.

So -- now this was lightness. But the results were consistent with the previous experiment, just looking at two different facets of an image.

And in reality, you look at all of it at the same time. And there's more experiments that need to be done.

But nevertheless, these were the first experiments ever done that took into account the perceptual transparency color sission issues as they occurred in the real world. So

they have a lot of credibility.

Q. The Henry studies did use a small amount of observers; is that right?

A. I'm sorry. I didn't hear.

Q. Dr. Henry's studies used a small group of observers; is that right?

A. Yeah. I mentioned, the budget wasn't very large. He -- in the SEAVES experiment in the Great Smoky Mountains National Park, he had two observers, two graduate students of his.

When he did the follow-on experiment with the lightness, he used eight observers. There's a paper which he described this experiment and he calls these naive observers.

These are not observers he trained on visibility. He picked neighbors and things like that. The experiment was done from his backyard where he happens to have a good view.

So -- so -- but he wanted to see what happened with people that were not trained in the process. They had to be taught on the instrument, but not taught about what they were looking for.

One person did it all wrong, and he describes that in his paper.

But that's sort of the essence of it. They been done on a relatively low budget with small numbers of people.

Q. Does the literature suggest a hard threshold for perceptibility of being able to detect a change in visibility or a range?
A. It's a range. And I mentioned detection probabilities of so many percent.
You can just sort of visualize it as a distribution at some low number, some isolated superman will be able to tell something's going on.
As you get bigger and bigger changes, small percentage of the population will be able to see what's going on.
By the time you get to 1 deciview, if you use Henry's numbers something not more than 17 to 35 percent that will be able to detect what's going on.
So it's a growing number and varies from person to person, and everybody will respond differently.
Q. Thank you, Dr. Tombach.
I would like to turn now to your opinions in this case.
First thing I think you said you were asked to look at was what were the projected impacts on visibility in North Carolina from TVA emissions in 2013 under the TVA 2013 plan.
Could you give us your overall conclusions on that question, and then we will talk about how you arrived there?
A. Sure. In 2013, I looked at the outputs of TVA modeling, using the emission in TVA's 2013 plan and converted them to visibility.

And the conclusion is, that the impacts of the TVA sources on visibility in the Class One areas in 2013, can be expected to be very small, below the 1 deciview number that we have been talking about. So very likely, almost 100 percent likely to be imperceptible.

The number turns out to be at the Great Smoky Mountains National Park, 0.4 deciviews, on the average of 20 percent of worse days of the year. And about 2.5 deciviews on 20 percent clearest days of the year. Very small number.

What that means is, if you have those plants equipped in that way, then you turn them off. The amount of visibility change would be not noticeable.

Q. And you used the model outputs that were given to you by Alpine Geophysics and the TVA modelers?

A. Yes. CMAQ and CAMx PSAT outputs from TVA models.

Q. And then you were responsible for calculating the light extinction using your crew.

A. Yes. Actually in some cases they had saved me the trouble of doing that. They had concentration of various components and calculated extinction conditions in other cases I calculated. But I checked the numbers and agreed with them.

Q. Where did you look at the visibility effects? Where were the places that you looked at the impacts?

A. Well, we looked at all the Class One areas in North

Carolina, the four Class One areas on the western end of the State, and one on the eastern coast. And then also three counties in the middle of the State that are concurrently nonattaining PM 2.5.

Q. I think you said you looked at the difference between what's projected, and if all the TVA plan plants turned off?

A. Yes.

Q. That was called a zero-out run?

A. Yes. You could call it that, yes.

Q. And I think you also mentioned you looked at the 20 percent best and worst days. Can you explain that to us looking at it that way?

A. Sure. What I mean here is, if you take the model outputs, and every day has a average level of visibility impairment assigned to it due to the class -- and you insert the visibility impairment numbers in increasing order. So there are 365 numbers for the year, then. The worse 20 percent days are the 20 percent of the days, 71 days at the high end, where the visibility is the worst. And the best 20 percent days are the 71 days at the low end, where visibility, according to model is the best.

This is based on total visibility. Not on impacts. I lead you astray there. Based on what the visibility was on those days.

Q. Why did you look at it that way?

A. That has become a convention as a result of EPA's regional haze rule. EPA set up regional haze rule to require that states set up programs to improve visibility on the 20 percent worse days, such that by 2064, or as soon thereafter as possible, they achieve what is called, "natural conditions". Which are conditions uninfluenced by man.

They also require in the Regional Haze Rule, that on the cleanest 20 percent days, that there be no deterioration of visibility. That it continue to be at least as good as it is now.

So those metrics have worked their way into a common practice since then.

Q. If I could ask you to turn in your exhibit notebook to what's been marked for identification as Defendant's Exhibit 428.

And Ms. Shay will kindly put it on the screen, as well. Thank you.

A. All right. I have it.

Q. What is Defendant's Exhibit 428?

A. Okay. Well, this is a graphical representation of the first conclusion I had just presented.

In the top half of the figure, there are bars, that one bar per receptor. As you read across the bottom, the left three bars are for the three nonattainment counties. And

then the rest of the bars are for Class One areas.

The modeling grid has four cells covering Great Smoky Mountains National Park.

So there are four bars of G-R-S-M, Great Smoky Mountains, number one, two, three, four for those.

Then there's a bar for L-I-G-O, which is Linville Gorge. There's a bar for S-H-R-O, which is Shining Rock. And a bar for S-W-A-N, which is Swan Quarter, and there are some others down the side we don't need to address here.

And the heights of the bar represent what the model calculations produced as the impacts of TVA 2013 emission scenario on the worst 20 percent days. And the answer is in deciviews.

This is, as you said, zero-out calculation.

In other words, the height of the bar is the difference between not having the TVA at all and having them run through the conditions for 2013.

Q. I want to stop you for a minute, that's -- there are two parts of this. Are you talking about the top or the bottom?

A. I'm sorry. You're right. I looked at this slightly fuzzy screen, talking about wrong thing.

Everything I said so far is about either. But now when I switch to TVA, it's the bottom half.

Q. Top half is North Carolina EGUs?

A. The top is the same calculation for North Carolina sources, under the Clean Smokestacks Act expected in 2013. So that's the comparison of the two situations.

And North Carolina one is another zero-out situation. It's with and without North Carolina power plants.

Q. And what are the results showing?

A. Well, let's start with the bottom panel, TVA. And what we see is, except for Great Smoky Mountains, all of the impacts averaged over 20 percent worst days are .15 deciviews and under, quite small.

At Great Smoky Mountains, they're higher. They go up to about .35 deciviews or thereabouts, they're twice as high. So we see, of the Class One areas and the other areas modeled, the largest impact on TVA sources are expected to be in 2013 at Great Smoky Mountains National Park.

Now, moving to the top panel, that's the North Carolina ones. And please note now the vertical scale is different. The bottom one goes from 0 to .5. The top one goes from 0 to 1.25.

So we have more range. And there the pattern is reversed. And in North Carolina we see almost no effect of the North Carolina sources. Their four bars are down in the tenth deciview range and under.

But the effects on the nonattainment counties are approaching one deciview on those days. And in the three

Class One areas, Linville Gorge, Shining Rock and Swan Quarter, they range from about .8 down to about .4 deciviews.

So what we see is, the two are almost mirror images of each other. The local sources effect central North Carolina and the eastern slope of the Appalachians, and the TVA sources that affect the western end of North Carolina.

The other thing we concluded is that the impacts of the TVA sources are larger -- try that again. Impacts of the TVA sources are generally smaller by national level from those from North Carolina's own sources, except at Great Smoky Mountains National Park.

Q. Just a few points of clarification.

This is under TVA's 2013 compliance plan, correct?

A. That's right, for the bottom half.

Q. And are you aware what Mr. Molenar shows as a significance threshold for his analysis, what he considered to be a significant perceptibility change?

A. Yes. Well, Mr. Molenar used 1 deciview. That was actually STI modeled -- did the calculation for 1 deciview and he just borrowed them.

Q. And in this bottom part of Defendant's Exhibit 428, are all of TVA's impacts below Mr. Molenar's significant threshold?

A. Yes. They are .4 and below. So even at Great Smoky

Mountains National Park, they are well below Mr. Molenar's 1 percent, 1 deciview threshold.

Q. And if you would, we have sort of a parallel figure on what's been marked as Defendant's trial Exhibit 429, which is the next exhibit.

What does this show us; what does Defendant's Exhibit 429 show us?

A. This is exactly the same analysis. But now we're looking at the 20 percent clearest days of the year in 2013. And again comparing the impacts of the North Carolina power plants at the top, and the TVA power plants at the bottom.

And we see several things that are different from previous plot.

One is that both for North Carolina and for TVA, the impacts are smaller in deciviews. The -- in TVA, the pronounced bump at the Great Smoky Mountains no longer exists. Great Smoky Mountains is really not much different than some of the other areas.

And then the biggest impacts moving up to the top panel in North Carolina, happen to be in the nonattainment county. So the patterns have changed, but all the values are less than they were on their worst days, both for TVA and North Carolina.

Q. I was going to ask you about this, they're smaller impacts because this is looking at S days, so these are

relatively clear days; is that why they are smaller?

A. These are relatively clear days. Now, that doesn't mean that you could have the smallest impact then. You could very well have the clearest day and have the biggest impact, and very clear. Since deciviews are in percent.

It takes less to have a certain increment in deciviews on a clear day than it does on hazy days.

The fact that we have a smaller number of deciviews on clear days, mean that the absolute impact is also smaller on those days.

Q. And are all of these impacts below the 1 deciview threshold of significance that STI and Mr. Molenar looked to?

A. Yes. In this particular plot, both for North Carolina and TVA, all of the predicted impacts on those 20 percent best days are below 1 deciview.

MS. GILLEN: Your Honor, at this time TVA moves for the admission of Defendant's Exhibit 428 and 429 into evidence.

THE COURT: Admitted.

(Defendant's Exhibit Number 428 and 429 having been marked, was received in evidence.)

Q. (Ms. Gillen) Dr. Tombach, turn back to Exhibit 420. We actually didn't make a separate exhibit of a figure there that I would like to look at. It's on page 40 on the expert

report and it's labeled as figure 5-10. Do you have that?

A. I have it, yes.

Q. And what is this figure?

A. Well, this is exactly the same information as the figure I talked about two back on the worst 20 percent days in 2013. The only difference it was done on a different modeling run in which the grid cells were 12 kilometers on the side, rather than 26 kilometers on the side. The fact of that is more grid cells, so we have more bars.

And particularly you notice that in Great Smoky Mountains National Park, now instead of having four bars, we have 19. So 19 cells that cover the park. And widely varying impacts at the park.

We added one new Class One area that didn't show up before on the 36 kilometer grid, which is the Joyce Kilmer Slick Rock Wilderness, which now is the very first bar of the 19 Great Smoky Mountains bars, labeled J-O-I-C.

Then we also now have multiple bars for both Shining Rock and Swan Quarter, because they occupy more than one cell.

So we have finer spatial resolution. But the picture they give of the overall situation, is consistent with what we saw two figures back, which is again, that the TVA impacts are well under half a deciview everywhere. And they are biggest at Great Smoky Mountains National Park.

And that's the only place that they are bigger than the impacts from North Carolina sources.

Q. And if you just turn the page in your expert report to page 41, figure 5-11. Is this the same focus of the best 20 percent days?

A. Yes. This is exactly the same information for the best 20 percent days. So it's analogous to the best 20 percent days we looked at two pages back, with more resolution, so we have more bars.

And you see, one interesting thing you see less visibility spatially, because clearer days does not have much gradiant in visibility. But the picture is exactly the same as before.

It's important for you to notice the scale on the upper plot is twice as high as the scale on the lower plot, so that the -- when the bars look like they are approaching the line on the TVA plot, it means they're getting up to one quarter deciview.

Whereas the bar approaching the top line in the North Carolina plot, means they are up to half a deciview.

The scale had to be larger because of the nonattainment counties in North Carolina showed bigger impacts than elsewhere.

Q. And again, the top half of figure 5-11, is zeroing out the North Carolina sources?

A. That's right.

Q. And the bottom is zeroing out the TVA sources?

A. That's right, in 2013.

Q. Thank you. If you would now turn to what's been marked as Defendant's Exhibit 430.

This is different. What is this chart looking at?

A. This chart -- we are now looking at the impacts in the zero-out sense. What we're looking at is the total level of haze from all sources. North Carolina power plants, TVA power plants, automobiles, midwestern power plants, sea salt, what have you, the whole thing all combined. Each Class One area, two bars. These are again for 2013.

The red bar on the left assumes that the TVA plants are operating according to its 2013 plan. The blue bar on the right assumes that the TVA plants are turned off.

So the difference in heights between the two bars is an indication of how much visibility would change in each of these locations, if you shut down the TVA network.

As you can see by looking at the top picture, which is for the worst 20 percent of the days, or the bottom picture for the best 20 percent of the days, the differences between the heights of the two bars are very small.

In fact, they are so small that in some cases you can't tell a difference. That is an illustration of the impact numbers we have, like quarter deciview, things like that,

how they look like when you add -- relate them to the total, total haze. So a quarter deciview is almost invisible on this plot. So the conclusion is that most of the haze is not due to TVA plants.

Q. When you say total, that's all sources in the entire modeling; is that correct?

A. Right. Right.

Q. And what does it suggest about the issue of haze?

A. Really says that -- and I think everyone knows, is that haze in the southeast is due to a lot of sources of all kinds, distributed over a large geographic area.

The fact the bars are fairly uniform in height, it says that we have similar conditions everywhere. And the fact that there is very small change in TVA means we have a lot of other sources out there that are contributing.

We know there are a lot of other sources out there this points out the relatively small role that TVA plants play in North Carolina haze.

MS. GILLEN: TVA would like to move the admission of Exhibit 430 into evidence.

THE COURT: All right. Let that be admitted.

(Defendant's Exhibit Number 430 having been marked, was received in evidence.)

Q. (Ms. Gillen) Dr. Tombach, if you would now turn in your Exhibit book to what's been marked as Defendant's Exhibit

432.

And this is a page from your expert report. I'm sure it looks familiar. And if you would focus on the table at the top of the page which is labeled table 5-4?

A. Yes.

Q. Can you just explain to us what this table is looking at?

A. Okay. The question arises when you're talking about visibility improvements, how do they distribute over time. We looked at the 20 percent worst days and 20 percent best days. But in general, how much do we get in various ranges.

So this table summarizes some information as to impacts in 2013 from the TVA sources, where we are now looking at daily values. And we sort them out to 365 daily values.

And we pick out of them, how many of them are under a half deciview, is the first column. Between a half and one deciview is the second column. Between one and two deciviews is the third column. And greater than two deciviews is the fourth column.

And so these are daily values. And then I've converted them, instead of giving number of days, I've given them to you in percent of days of the year.

So, and I look at two receptors, one is Great Smoky Mountains National Park Look Rock site. The other is the Linville Gorge site.

The reason I picked those, those tend to be -- if you remember the previous bars, those tend to show the largest impact from TVA sources.

So the first two rows, both at Look Rock compare the distribution of the North Carolina power plant impact over the year with the TVA impacts.

We see, for example, at Great Smoky Mountains where we already know that TVA sources are likely to contribute more in 2013 than they -- North Carolina sources. We see they are reflecting the in fact that 92 percent of the North Carolina impacts, 92 percent of the days, the impact is less than half a deciview. Whereas only 84 percent of the time is it less than half a deciview due to TVA sources.

Going to the other end of the scale, we also see similarly that 1 percent of the North Carolina impacts are greater than two deciviews, means three or four days of 1 percent.

Whereas 2 percent are above two deciviews from the TVA plants.

And moving over to Linville Gorge, which is on the other side of the Appalachians in the same general area.

We see a slightly different situation. Now we see the TVA impacts have a higher percentage under the higher deciview, 88 percent, than do the North Carolina impacts, for which only 78 percent are under two deciviews.

And we see the reason for that is when we go to the right-hand end of the chart, 4 percent of the North Carolina impacts of Linville Gorge are above two deciviews. Where none, zero percent of TVA impacts at Linville Gorge are over two deciviews.

So this gives you a feel of how things distribute over space and time, and gives you little better understanding of what's going on.

Q. If you can turn now, actually turn back to what's been marked as Defendant's Exhibit 431. What is Defendant's Exhibit 431?

A. This is a graphic representation of the same data used to construct the table we just talked about. I have to explain the graphs a little bit.

Across the bottom -- let's pick one graph. Let's take far, northwest one, upper left one. That's for looking at the contributions in North Carolina power plants at Look Rock, Great Smoky Mountains, Tennessee.

What we have across the bottom is the impact in deciviews, starting from 0.1 then going up to some large number, then have more above, because sometimes you go above that.

On the left-hand side is the frequency in days per year that values are below whatever number is on the bottom. The upper left plot the bar goes up to 280 days. So we are

saying on 280 days of the year, the impacts on North Carolina emissions at 2013 at Look Rock are likely to be less than a half deciview, very small.

Then we see that a very, very smaller number of days, maybe we are now down to 25 days, are between-- .5, I meant to say .1 earlier.

Now 280 days below .1 deciview.

And we have, then maybe another 25 that are between .2 and .1 and so forth as we go on. So that's what the bars tell you.

Now the dotted red line on the top displays the same information in a different way as a cumulative frequency. So the scale for it is on right side in percent of the total. And we can see how those bars relate to, at different levels.

So, for example, again. At the location of the very first bar, there's a dot in it that's maybe at the 75 percent mark. So we're saying 75 percent of the days are below .1 deciview. That's about 280 days. So I think my math is about right.

And we see that if you go up to the .2 number, we've gone up a little bit, maybe it's 80 percent now instead of 75. So we are saying that a total of 80 percent of the days are below .2 deciview.

Let's go up to one deciview. At one deciview we're up

to 95 percent maybe. So we're saying that 95 percent of the time the impact is under one deciview.

So this is a different way of displaying the same kind of information I had in the previous table, gives you a little more detail so you can see what happens.

And what's, I think, an important point here to notice, is that as you go to the right-hand end. Sometimes we have a little bump that the impact is higher -- that isn't a smooth distribution, keeps getting better.

Suddenly there's a single bump or something that's higher. So that is one of the problems of trying to characterize what's going on with visibility with single numbers.

Depending on which single number you pick, it may not be at all representative of what goes on with the rest of the curve. You need to have ranges of numbers so we have averages.

Now having given the instruction, so we have same sources and same location as we had on the table. Great Smoky Mountains Park, Look Rock left side, North Carolina on top, TVA on bottom. And Linville Gorge on right side. North Carolina in 2013 on the top, Linville Gorge in 2013 on the bottom.

And we can basically see, just qualitatively a couple of things.

One is, if you look at the TVA impacts for Look Rock, you will find more of the high bumps bars at the higher deciview range, than we did for the North Carolina sources. The same thing we saw on the table. Meaning the TVA has a greater impact on the Great Smoky Mountains and we see a worse pattern at Linville Gorge.

Q. Do these charts assume that all 365 days of the year are clear, you can see?

A. Yes. That's an artificiality of many of these analyses, and that is that the calculations -- we calculate pollutant concentrations. Then we convert the visibility, and don't take into account the fact that visibility may be impaired by cloud, fog, rain, mist, things of that sort.

So it could very well be we have a foggy day, and doesn't matter what air pollutant emissions are. Because if you change them, it will still be foggy, can't tell the difference.

So in that sense this is an optimistic representation of impacts -- of distribution impacts and resources. In reality there will be days when you don't see any impact at all.

MS. GILLEN: At this time, Your Honor, the TVA would like to move Defendant's Exhibit 431 and 432 into evidence.

THE COURT: Let it be admitted.

(Defendant's Exhibit Number 431 and 432 having been marked, was received in evidence.)

Q. (Ms. Gillen) Dr. Tombach, so far I believe we have been talking about the entire TVA fleet of coal-fired power plants, 11 coal-fired power plants; is that right?

A. Yes, that's right.

Q. Did you ever -- was there ever any modeling that you could look at that separated out certain of TVA plants?

A. Yes. I looked at some of the impacts, based on groups of TVA plants and grouped them geographically. The three TVA plants in eastern Tennessee. The four plants in western Tennessee, and two plants at the western end of Kentucky, and looked at the contribution separately to get an idea of the effect of geographic location on impacts.

Q. This was with modeling of the 2002 inventory?

A. Yes. In this case it was current, meaning 2002 conditions, simply because -- well, that's the only runs that were done for this period.

Q. We won't go into great detail about these. But generally what were the findings when you looked at groupings of TVA plants?

A. Okay. Considering present day conditions, present day emissions -- not present day, 2002 emissions from TVA, the Kentucky contribution was by far the smallest. They -- today, without any future emission reductions, contributed

on the 20 percent worst days, less than .8 deciviews. So it's already below a one deciview threshold.

The Alabama contribution was a bit higher. The peak day was 1.6 deciviews. And then went down from there. Actually, I'm sorry. Kentucky .8 also peak day. So it's even smaller than 20 percent days.

Any way, so Alabama was 1.6 deciviews. So it's a bit over. In western Tennessee, it was a bit higher yet of 1.9.

Then the really big effects came from the three eastern Tennessee plants where peak values were up over several deciviews.

Q. Would you expect those same patterns to hold for future -- for 2013, the same sort of relationships between the geographical regions?

A. Mostly, yes. It depends a bit on where the controls are placed as to which areas see the biggest reductions.

But the geographic difference in say between east and west are so large, that that should prevail no matter way.

And of course in cases like Kentucky, where we are already at the peak value of 8 deciviews, that number will go down and become very small compared to 1 deciview.

Q. Dr. Tombach, I would like to turn to the opinion you reached as to the difference between the visibility impacts under TVA's 2013 plan, and the North Carolina Clean Smokestacks Act plan.

What did you conclude about the difference between those two plans and their impacts on visibility?

A. The difference is really minute. On the 20 percent worst days, the biggest difference was about 0.12 deciviews. So the Clean Smokestacks plan was 0.12 deciviews cleaner, better visibility than TVA 2013 plan.

On the best days it was well under 0.1 deciviews.

So these are in the vicinity of 10 percent of 1 deciview number that Molenar uses, perception threshold.

The conclusion I come to, you won't be able to tell the difference between the two scenarios.

Q. If you would please turn to what's been marked for Identification as Defendant's Exhibit 433. What does this figure show?

A. Okay. Well, this is a representation of what I just said. And the top panel is worst 20 percent days. The bottom is for the best 20 percent days. The vertical scales or height of the bar difference between the TVA 2013 plan and the 2013 CSA plan for TVA.

As you can tell by the number of bars, this is the 12 kilometer modeling. The very highest bar is at Joyce Kilmer model and that's at 0.12 deciviews. Everybody else is less. So that's quite.

And the bottom plot, the very highest bar is at one location in Great Smoky Mountains National Park where its

about 0.07 deciviews, which is even smaller yet.

So the differences are very, very small, compared to anybody's comprehension of what visibility perception threshold would be.

Q. That's what I was going to -- they are compared to the 1 deciview significant threshold; how do these compare?

A. You won't be able to tell the difference.

Q. And if -- in terms of visibility impacts, if the North Carolina Clean Smokestacks Act were imposed on top of what TVA projects it will be doing in 2013, would you be able to tell the difference?

A. No. The height of the bar is the difference. And no you won't be able to tell what happened.

MS. GILLEN: Your Honor, TVA moves to admit Defendant's Exhibit 433 into evidence.

THE COURT: Let it be admitted.

(Defendant's Exhibit Number 433 having been marked, was received in evidence.)

Q. (Ms. Gillen) Dr. Tombach, did you review the expert reports prepared by STI Messers Chinkin and Wheeler?

A. Yes I did.

Q. Did you have an opinion about conclusions they reached from TVA coal-fired EGUs?

A. Well, I had several conclusions. First of all I was told by TVA that their emissions estimates were not

realistic for 2013 for TVA. And so that would lead you to deduce that their estimates of impacts are going to be too large.

They represented their results in two ways that I was a bit uncomfortable with.

One way is, they gave the results for the highest day, the predicted visibility impairment, on the day that had the biggest predicted visibility impairment. Not the worst day, but the biggest improvement.

And what I tried to show with my statistical plots is the tail end of distribution impact, doesn't tell you what's going on with the rest of the distribution. It could be an isolated number. So it is not terribly informative as to what the impacts are.

Then they gave a value above 1 deciview to indicate how much perceptible improvement they said would occur. So if one accepts their values, the problem is that 1 deciview is a pretty conservative estimate of perception threshold. And not a lot of the people will be able to tell that difference.

One more I had in mind a second ago.

Q. Did they look at North Carolina impacts on North Carolina?

A. No. They did not look at North Carolina impacts at all. And they were only focusing on TVA impacts.

Q. And did you have an opportunity to review the expert reports submitted by Mr. Molenar in this case?
A. Yes, I did.
Q. And do you have an opinion on the visibility impacts as to what he predicted the visibility impacts to be from TVA's coal-fired power plants in 2013?
A. Okay. Well, the impact numbers that are in Mr. Molenar's report, are copied letter for letter from the Chinkin and Wheeler report. The three tables that he has in there.
So everything I've said about those tables, applies to the Molenar report also.
Now, the contribution that Molenar made was to generate computer-enhanced photographs of visual conditions. And those pictures actually were borrowed then, and put in the Chinkin and Wheeler reports. So there was kind of a cross-fertilization of the two reports.
So he used a model called "WinHaze" to -- which is a radiation transfer model, a simplified radiation transfer model, to try to simulate the effects of haze on different scenes.
I have some criticisms of that technique. I should first mention, pictures are a wonderful way to display things. And qualitatively, it's a great way to go.
But because of simplification and errors in the

process, and because pictures don't replicate the real world for reasons I've already explained, you cannot use them for quantitative demonstrations. They were trying to demonstrate the degree of improvement in a quantitative way, and you can't do that with pictures.

Worst of all were pictures where he split them down the middle where one side represented one condition and one side represented another condition.

And that picture procedure draws your attention to any differences between the two sides because of the line between the two.

Q. And Dr. Tombach, you've done this with me, so I would like you to show the Court, I think you have an illustration of what that dividing line does to the image.

And if the Court would like to turn to Plaintiff's book Number 6, and Plaintiff's Exhibit 301-C, I think Dr. Tombach can illustrate what the effect of the split has on the picture.

Plaintiff's Exhibit 301-C is the one we're looking at.

THE COURT: All right. Now I have it.

Q. (Ms. Gillen) Okay. And Dr. Tombach, would you just tell the Court the illustration that shows the fact of the line?

A. Okay. I hope, Your Honor, that the picture that you have is a better quality than the one I have here. This

demonstrates another weakness of pictures. I have streaks across mine, apparently caused by the printer, that put additional vertical lines, in addition to the splits between left and right sides. Hopefully yours doesn't have that.

So what we have here is a picture that on the left side has been altered to look as though they put a haze in, artificial haze in, so it looks like you can see 24.9 miles. On the right side of the split it's 30.6 miles. That's about a two and a half deciview difference.

So it should be perceptible to a lot of picture. And if you look at the other picture, you do indeed see that the left and right sides are slightly different.

But the reason they look different, is because the line in the middle shows there's a difference.

Now, if you take that line away, it will look very different. If you have a pencil or a pen, and you lay it across the vertical line between the two halfs of the picture, then look at the two halfs of the picture, it will look quite different. And in fact it will be very hard to tell the difference between the both halfs once you do that.

THE COURT: Okay.

MS. GILLEN: Thank you very much, Dr. Tombach. We have no further questions.

MS. LYNCH: Thank you, Your Honor.

CROSS-EXAMINATION BY MS. LYNCH:

Q. Good afternoon, Dr. Tombach.

A. Good afternoon.

Q. You described you described a lot of contrast relationship relating to visibility. If we could boil that down, I would appreciate that.

Sulfates are by far the single largest contributor to fine mass in the eastern United States; is that correct?

A. I'm sorry. I didn't understand your question or didn't hear it very well.

Q. Sulfates are by far the single largest contributor to fine mass in the eastern United States; is that correct?

A. Yes, that's correct.

Q. I think you testified earlier that fine particles are the main impairment for visibility; is that correct?

A. That's correct also, yes.

Q. And I think it follows then that the more particles that are removed from the air, the higher chance of visibility; is that true?

A. All other things being equal, yes, that is true.

Q. And the more controls that are placed on TVA's coal-fired power plants, all other things being equal, the more improvements in visibility we would see in the areas that are overlaying by the plumes from those plants; is that correct?

A. That's right.

Q. You walked us through some of the results that you generated based on the 2013 modeling done by Dr. Tesche and Mr. Molenar; is that correct?

A. That's correct, yes.

Q. And that modeling assumes that TVA will install all of the controls in its current Clean Air Plan; is that correct?

A. That's my understanding, yes.

Q. And you didn't look at whether those controls -- whether TVA's under any obligation to install or operate those controls that are contained in the plan, did you?

A. That was not the scope of my efforts. No, I did not.

Q. So you just took the modeling that you received from Dr. Tesche and Dr. Molenar and used that for your analysis?

A. My charge was to interpret the modeling results in terms of visibility.

Q. Okay. And that 2013 projected emissions based on TVA plan, is not reflective of current conditions; is that correct?

A. No. It's not reflective of current conditions.

Q. But you did conclude that if TVA does put all the controls on that are included in its plan, that it will significantly reduce TVA's impact on visibility to the region; is that correct?

A. That's correct, yes.

Q. And if TVA's required to put on additional controls beyond what it may plan at this point, that will improve visibility?
A. Well, my conclusion was that the improvement then would be imperceptible. So I would have to say it doesn't improve visibility, but you can't tell it changed.
Q. So it doesn't improve visibility, but you can't tell that it changed; is that what you just said?
A. That's what I'm saying, yes.
Q. You talked a little bit in your direct examination about what constitutes a perceptibility improvement?
A. Yes, I did.
Q. And EPA has determined, has it not, that a 1 deciview change, causes a visibility impairment?
A. I wouldn't say determined. I would say, has stated.
Q. Okay. EPA has stated that a 1 deciview change causes a visibility impairment; is that true?
A. That's correct. I haven't seen any documentation to support that number, however.
Q. You have seen their statement in the Federal Register to that effect?
A. That's where they state what they consider 1 deciview change to be. But they don't let me know how they got that number.
Q. And I believe in the same register announcement, EPA

stated one half deciview change contributes to visibility impairment; are you familiar with that?

A. Sounds to me like you are quoting from a BART Rule.

Yes. They have stated in that case, that for purposes of BART, that they consider that half a deciview impact on a 98th percentile day, contributes to visibility impairment -- a contribution to visibility.

Q. Under that same register notice, EPA in fact cited to studies that I think you talked about earlier, indicating that they did in fact consider those studies, and still determined that a 1 deciview change causes visibility impairment. And that a half deciview contributes to visibility impairment; is that true?

A. That's true. I think there's an important point here. The issue in the BART Rule and preamble that you are quoting these things from, is not whether impairment is perceptible or not. It is whether impairment could contribute -- there's enough of a contribution that you should be interested in it.

Let me give you an analogy with the PSD Rules.

The PSD Rules tell you -- give you increments that you could increase say PM 2.5 concentrations by.

But the federal land managers hold sources to numbers very much smaller than those, because they don't want increments used up by one source. So, to leave room for

multiple sources, they are interested in numbers that are small.

We have the same issue in visibility. For the BART Rule, they want to consider the possibility that multiple sources might be contributing. So you don't want one single source to create a perceptible impact, because then the others will aggravate it.

So they want numbers that you can have multiple sources, and still not perceptible impact. They are picking numbers that are conservatively lower, which makes sense for their purposes, but does not address the perceptibility question.

Q. I think you touched a little bit on use of photos and WinHaze models in your direct examination. I just want to clarify that you do agree that a photograph relating the effects of particles -- that particles have in effect of landscape features, is the most simple and direct form of communicating visibility impairment; is that true?

A. That may be a little too much. But let me paraphrase it in my own words.

A picture is a very convenient way of demonstrating visibility impairment to the layman. Because it's very hard to visualize, mentally, all these deciviews and things we are talking about.

So it is a great way to demonstrate that. But that's

as far as what you go with it.
Q. And in fact, there is no other method besides photographs to qualitatively look at these changes in visibility that we have been talking about, is that true?
A. I missed the first part of that.
Q. There is no other method besides using photographs to qualitatively see changes in visibility that we have been talking about here?
A. No. I have no objection to using it for that purpose, as long as one understands the limitations and in fact they are imperfect representation of the real world.
Q. And that's perhaps why EPA's regional haze rules in fact recommends States use computer-based scene optics modeling tools, to present to the general public, the anticipated change in visibility?
A. Exactly.
Q. And I just want to clarify. You agree that the WinHaze model's a respected tool in the air modeling community, for modeling changes in WinHaze visibility?
A. The WinHaze tool has been accepted by the regulatory modeling community in the United States. But we need to elaborate on that a little bit.
The model is a simplified radiator transfer model. So it doesn't do things right. It doesn't handle absorption. The carbon particles I mentioned. Doesn't get the colors

quite right. If you look at the colors, the hazy pictures are too blue. You cannot deal with cloudy days. You have to have a perfectly clear blue sky in the original picture. There are very many limitations in it. As long as you recognize the limitations, yeah, it's a useful tool. And you can use it then to portray in a general sense what's going on.

But you cannot represent a lot of conditions. You cannot represent with any credibility. You have to know what you're doing. That's actually one of my concerns is the WinHaze model is easily available. Anyone can run it, even if he or she doesn't know what they are doing, and it will give you a picture. So it's garbage in, garbage out you. Have to know what you're doing.

Q. I believe if we could show Dr. Tombach the deposition he gave in this case that was back on June 28, 2007, do you remember having your deposition in this case?

A. No, I remember.

Q. Okay. I'm just going to show you page 83, lines 5 through 8 from that deposition.

You were asked in your deposition -- "In your expert opinion, is WinHaze a respected tool that air modeling community for modeling visibility scenes?"

Your answer is, "Yes". Is that still your answer today?

A. Yes. I probably was a little -- little too brief with my answer. But generally it's yes. My only comment was that there are limitations as to how it should be used.

Q. Okay. And you're also aware that WinHaze has been used by the National Park Service, National Forest Service, as well as EPA, for showing changes in visibility?

A. It's been used by me to show change in visibility.

So that just says it's a useful tool for showing, in a general sense, what's going on.

Q. All right. You testified at the beginning of your direct examination that you were asked to look at visibility impacts from the Tennessee Valley Authority System on North Carolina.

Were you asked to look at visibility impacts in any other state besides North Carolina?

A. No, I wasn't asked. But the results I got did include Shenandoah National Park in Washington, D.C. and they are included in the plots I went through today on the right hand side. I didn't discuss them.

Q. For the Great Smoky Mountains National Park that straddles the border between North Carolina and Tennessee; is that correct?

A. Yes.

Q. So you included part of the Great Smoky Mountains National Park that's in Tennessee?

A. Yes.
Q. Did you look at any impacts on Alabama?
A. No.
Q. Did you look at any impacts in Kentucky?
A. No.

MS. LYNCH: We have no further questions for Dr. Tombach.

MS. GILLEN: No redirect, Your Honor. Thank you.

THE COURT: All right. Thank you, Dr. Tombach. That will complete your testimony, and you are excused.

THE WITNESS: Thank you.

THE COURT: All right. We will take a 15-minute recess.

(Recess.)

THE COURT: Mr. Fine.

MR. FINE: Defendant Tennessee Valley Authority calls as its next witness, Dr. Grigal.

THE COURT: All right, sir.

THEREUPON, DAVID GRIGAL, being first duly sworn, testified as follows during DIRECT EXAMINATION BY MR. FINE:

MR. FINE: Your Honor, we're going to be working from TVA Exhibit Book Number 17.

Q. Good afternoon, Dr. Grigal.
A. Good afternoon.
Q. Could you please state your name?

A. David F. Grigal. G-R-I-G-A-L.
Q. And where do you currently reside?
A. I live in Roseville, Minnesota, a suburb of St. Paul, Minnesota.
Q. What is your current employment?
A. I'm a retired professor, Professor Emeritus at the University of Minnesota. I do some part-time consulting on an *ad hoc* basis.
Q. What is your understanding of your role in this case?
A. I was called by TVA to try to assess the ecological impacts of the what I'll call later in my testimony delta deposition. The difference in deposition of acids and/or mercury on ecological resources in the State of North Carolina and adjacent states.
Q. Just so it's clear from the get-go Dr. Grigal, what do you mean by delta deposition?
A. By delta deposition in my expert reports, I based the delta deposition on the difference in modeled deposition between what TVA would put out in 2013, as compared to what they would put out in 2013 following this Clean Smokestacks Act as modeled by North Carolina.
I did not use TVA modeling results. Partly because I was sceptically convinced that they would probably come in with a lower number. I wanted to be more conservative in my estimates. I used North Carolina numbers.

Q. If you could please, sir, give us a summary of the opinion that you reached?

A. I based on my analysis, which I'm sure we will go into in some detail, I determined that the alleged delta deposition would have no measurable -- no measurable impact.

That is, we could not literally measure the impact on deposition. And as a consequence, we could not measure the impact on ecological resources, using the metric I used in my report. Couldn't measure it. So trivially small, it was unmeasurable.

Q. Ms. Shay and Dr. Grigal, I would like to ask you to turn your attention to a document marked for identification as Defendant's Exhibit 412.

Do you recognize that document, sir?

A. Yes, I do.

Q. Could you tell us what it is?

A. It is a brief summary of my background, my professional background.

Q. Including education, work history, publications and the like?

A. Correct. Correct.

Q. Using that as a point of reference, Dr. Grigal, could you please outline for us your educational background?

A. Yes. I received my -- actually I attended a, what we now call a community college, at that time it was called a

junior college, a local two-year college in my home area. And then I went to the University of Minnesota where I received a Bachelors and Masters degree in forestry.

Then as it was in mid-educational career, I switched horses and received a Ph.D in soil science. I received that degree in 1968, forty years ago. I moved on to Oak Ridge National Lab as a post-doctoral fellow in ecology. I spent a couple of years as a post-doctoral fellow in ecology at Oak Ridge.

Q. Dr. Grigal, if you could please continue with your work history in terms of where you worked, what duties you performed?

A. After the two years post-doctorate at Oak Ridge, I joined the staff for a while, but moved on and ultimately actually back to the University of Minnesota on the staff there, arriving there in 1970. And I retired from the University then in 2000, after 30 years in a staff position.

I was a member of the Department of Soil. And eventually changed the name to Soil, Water and Climate with a joint department in forestry.

Q. Before we turn in a little more detail to your academic career, what were duties at the Oak Ridge National Laboratory, sir?

A. Briefly, in two words, nutrient cycling. The movement of elements through the southeastern ecosystem. Centered of

course on Oak Ridge National Lab and the reservations around Oak Ridge.

But one of major research foci was the movement of calcium through the course at Oak Ridge National Laboratory. I did a number of other research studies.

Q. Apart from your period of time at the Oak Ridge National Laboratory, what experience do you have with the natural systems in the southeastern United States?

A. During my academic career, I became, very fortuitously, a reviewer.

By that I mean, during the hay day of acid rain, that is during the beginning in the late seventies, actually near the time I retired, there were a large number of research projects trying to understand the impacts of acidic deposition in all its forms on natural ecosystems.

I was a person that became often called upon to -- perhaps at the frequency of once every six weeks or eight weeks to travel to some location and review research being done sponsored by EPA or Electric Power Research Institute, Department of Energy, Forest Service, folks like that.

So I visited the southeast many times as a reviewer. These reviews usually took place both in the field and in the conference room.

I spent in addition to my residence here in Tennessee, I spent quite a bit of time in the southeast.

Q. Dr. Grigal, Defendant's Exhibit 412, appears to list a number of publications that you were responsible for; is that correct, sir?
A. Yes, sir.
Q. Could you just summarize for us the areas in which you have had published work?
A. Some folks called me a dilettante in the sense I investigated a number of areas. Partly this was because of funding, where the funds were. Partly was because of interest of myself or my students. Partly was because of a question that arose that needed an answer.
But in general I would say that I had two or three major foci, as they were. And one clearly was the movement or response, I should say of ecosystems to disturbance, various kinds of disturbance, forest fire, acid deposition, even things like cultivation, reforestation.
And by response of disturbance, it depends on the response variable. Sometimes it was just the rate of regeneration, the rate of carbon accumulation, the cycling of nutrients, all of these things most often in the context of some disturbance, both man-caused and or natural.
Q. In the course of your career, have you engaged in consulting activities?
A. Yes. In fact, many of my review trips that began, as I said, probably in 1980, were actually outside activities.

They were outside the realm of the University. They weren't supported by the University. And they were called consulting, by want of a better term.

But then as I approached retirement, I had a retirement phaseout period of about five years at a reduced pay. That reduced pay generated some necessity for a little bit of consulting.

Since I retired I operated on an *ad hoc* basis. I don't look for projects. But once in a while a project will look for me, if it sounds interesting, I will do it.

Q. For whom have you done this consulting?

A. I've done a little bit, I was an expert witness, a case didn't go to trial on a case of acid deposition. I think the record shows the Ohio Edison case, a few years ago.

I've done some work for the Department of Justice, working with Native American claims on land valuation and management of their forests on reservations.

I've done work on environmental impact analysis. I've just developed a growth model, that is an index for growing trees on soils of Minnesota so soil scientists can, and a land appraiser for property tax purposes, can decide how valuable the land is, based on the soil, based on my model, rate of tree growth, things like that. As I say sort of --

Q. You mentioned work with the Department of Justice. Have you done work for other government agencies?

A. Not any explicit consulting, other than -- well, the Aspen growth was done for the Natural Resource Conservation Service, Forest Service, I may have done some for the Forest Service.

Q. Have you conducted any research for government agencies?

A. Yes. Certainly in the context of my university position, we had funding from NSF. We had funding from --

Q. What is NSF?

A. National Science Foundation. Funding from National Forest Service, funding from Department of Energy. And I conducted research using their funds through my university position.

Q. What about the Environmental Protection Agency?

A. I am trying to -- off the top of my head, I do not know if I received any funds from the Environmental Protection Agency to pursue research.

I certainly was a reviewer for them. I don't know if I -- many agencies thought I was very good at reviewing the research and being a critic of their work, but for some reason didn't give me money to do my own work. I couldn't quite understand that.

Q. Which agencies did you work for as a reviewer of other people's work?

A. EPA, National Science Foundation, US Department of

Agriculture, U.S. Forest Service, Department of Energy, Electric Power Research Institute. May have been others, but -- and as I said, I was called in usually on a committee or the chair of the committee to review a research project.

Q. I believe that your resume, or excuse me, the information reflected in Defendant's Exhibit 412, reflects that you are a licensed soil scientist. Would you explain that, sir?

A. Yes. The State of Minnesota has a licensing program for architects, engineers, certainly an engineer can't design a bridge -- even though we don't do it well in Minnesota -- can't design a bridge without being a licensed engineer.

By the same token there's a licensing program for soil scientists through the State of Minnesota, so you must submit credentials, keep up with continuing education, then you can do work and sign off as a licensed soil scientist.

Q. What field of endeavor is covered by the certification as a licensed soil scientist?

A. That is a -- such issues as drainage, as some of the areas of waste disposal, both solid waste and secondary effluents, things like that.

Q. Are you a member of any professional organizations?

A. Yes, I am. I continued, even in retirement, I'm a member of the Triple AS, American Association for

Advancement of Science, the American Society of Agronomy and its Coal Scientists of America, Ecological Society of America, Society of Wetland Scientists in Minnesota, a Professional Soil Scientist Association. I'm a member of those.

Q. Dr. Grigal, a few questions concerning your academic experience. I believe you said -- well, remind me if you would, I apologize for this. What was your department at the University of Minnesota?

A. My department was the Department of -- my payroll, my paycheck came from the Department of Soil, Water and Climate.

But at the University of Minnesota, as in many universities, there are -- let's call them "supra departments" -- not super, but supra departments that transcend payroll lines. The graduate departments often do this.

So you may have a graduate faculty which consists of members of other departments, all of who advise students, conduct examinations, trying to certify those students after approval of their thesis as getting advanced degrees.

So even though I was a member of the Department of Soil, Water and Climate, I was a member of four different Graduate Programs in the University.

Q. Could you describe which Graduate Programs you were

participating in?

A. The department -- or the Graduate Program of Soil Science, of course. The Graduate Program of Forestry, the Graduate Program in Ecology, and the Graduate Program in Water Resources.

All of these areas sound sort of the same. And certainly my expertise lies in the intersection of those resources.

Even though I was in Water Resources, I'm certainly not an expert on invertebrate fauna in waters. But my expertise lies in the intersection of those areas.

Q. I would like to return to a comment you made in response to one of my earlier questions, Dr. Grigal. I believe you said one of the things you were studying was the disturbance of natural systems, either by natural or man-made impacts. You mentioned forest fires, for instance?

A. Right.

Q. Could you explain a little further what you were talking about?

A. Well, there was a time when ecologists -- and a time when I was receiving my education -- were interested in pristine environments, searched long and hard for systems that were untrammeled by man, or uneffected by disturbance.

And it became clear that they had to look so hard for something undisturbed, that disturbance must be the norm.

And we would be bereft if we didn't study disturbed systems. We should be studying the systems that exist, not some kind of an exalted vision that we have that could never be reached.

So early on I decided that disturbed systems were the way to help man, that is us, man, understand what society does to disturb those systems.

Q. I think you mentioned a number of possible disturbances, including fire and logging, atmospheric deposition and reforestation after agriculture?

A. Right. Those are some of the things I looked at.

Q. Sir, you also mentioned that you had done some work in the field of what I call "acid deposition".

And I think you understand that we already had extensive testimony from Bill Jackson from the Forest Service, and of course Dr. Charles Driscoll on behalf of the Plaintiff on what I'll call the "mechanics of acid deposition".

But if you could tell us what your background is in the study and understanding of acid deposition?

A. Yes. I've read their transcripts of their testimony and they have covered it pretty well.

My early work in Oak Ridge was with calcium cycling. You've heard the word calcium come up quite a bit.

So in a sense, the acid deposition research is an

application of basic science. Just as you talk in medical, an area of basic science and apply it. Acid deposition is more or less applied.

The early work I did though was basic science and cycling of elements. All acid deposition is, is cycling of elements with the imposition of atmospheric pollutants. I did that.

I did work in Minnesota, there was some concern about setting some acid deposition standards. So I participated with a colleague in developing a model of acidification of soils that was used in that controversy, and also published in a peer-reviewed journal.

I pursued a number of research studies underneath that, the National Acid Precipitation Assessment Program. Which had very intense -- was a multi-federal agency program that had a very intensive period of about a decade till about 1990 when I was funded by them to pursue various kinds of research on effects of acid deposition.

Then as I said earlier, I did a lot of reviews of acidic deposition research, starting before 1980.

Q. Dr. Grigal, I believe you are aware that one of the other issues in this case is mercury deposition in North Carolina.

What exposure do you have to the issue of mercury deposition?

A. Mercury, I don't want to call it a late-comer. But scientists only recently have begun to realize the potential impacts of mercury deposition on systems.

That came -- or perhaps I should put it the other way that I was one of the early people to start looking at mercury in natural systems.

That was at the close of my University career, in about oh, in 1990 or so. I was already in my phase-out or beginning my phase-out.

We started to look at Mercury, and I continued that both I and colleagues and graduate students through to my retirement, and beyond my retirement, actually.

And even after my retirement, I've written a couple of scholarly reviews and peer-reviewed journals on mercury and ecosystems. Those were both published.

Q. I believe that you have described in some of the material I've read that you prepared, that you have a focus on quantitative description of the ecological impact?

A. Yes. I feel that qualitative, good, better, best, just doesn't really cut it with me.

Perhaps because of my scientific background, my training. Partly I think it's a personal quirk.

My son gets disturbed when we go on a canoe trip, and I count the number of steps on portage. My son doesn't understand why you're counting. I'm quantifying it.

The same way with the science. I've not been happy with the research that doesn't put a -- some kind of a handle, some kind of a number on things. So that's what I try to do with my work is to put numbers on things.

Q. Dr. Grigal, I believe you prepared two expert reports in this case?

A. I did.

Q. And if I could ask Ms. Shay to display at least a cover page of the Defendant's Exhibit 410. Turn to it in your book, if you would, Dr. Grigal?

A. Okay.

Q. Do you have that in front of you, sir?

A. Yes, I do.

Q. Do you recognize that document?

A. I do indeed.

Q. Could you tell us what that is?

A. It's an expert report that I prepared dated 23 February '07 at the behest of TVA examining -- the title is, "Ecological Effects of Changes In Atmospheric Deposition In the Southeastern States".

And the changes we're talking about here are the alleged delta deposition.

Q. Dr. Grigal, I believe you said that you prepared that report?

A. I prepared that report.

Q. Anyone assist you in the preparation?
A. I had no secretarial or intellectual assistance.
Q. Dr. Grigal, I would ask you if you would please look at Defendant's Exhibit 411.
And ask Ms. Shay if she would please display the cover page of that document.
Sir, do you have that document in front of you?
A. I do.
Q. Could you tell us what it is?
A. It's the supplemental expert report that I produced dated first of June, 2007, following Dr. Driscoll's supplemental report to my first report.
Q. And again, sir, did you prepare this report?
A. I prepared that wholly on my own.
MR. FINE: Your Honor, I would tender Dr. Grigal as an expert in soil science and ecology, and an expert in the ecological affects of acid deposition and mercury deposition at this time.
THE COURT: The record show that the Court so hold.
MR. FINE: And I would move the admission of Defendant's Exhibits 410, 411 and 412.
MS. LYNCH: Your Honor, just like to note the State of North Carolina's objection to expert reports, noting the previous ruling.

THE COURT: All right. The record will show the objections are overruled. And the 410, 411 and 412 are admitted.

(Defendant's Exhibit Number 410, 411 & 412 having been marked, was received in evidence.)

Q. (Mr. Fine) Dr. Grigal, if we could turn, at least for a while, to the question of acid deposition.

And again, I think as you have already recognized, we've had a pretty good primmer about acid deposition and its affects from Mr. Jackson and Dr. Driscoll; is that correct?

A. That is correct.

Q. With that as a baseline, Dr. Grigal, I would like to get into some more specific questions we need to get from you and present to the Court here today.

Dr. Grigal, there are a number of, if you will, units of measure that I would like to have some help with, if you could please?

A. All right.

Q. And first of all, there's some terms that we've used and terms of base saturation, acid neutralizing capacity and measurements of acid deposition itself.

Let's start with base saturation, if you wouldn't mind, sir. And just give us an idea of what are we talking about with that term?

A. Mr. Jackson described it. I used in my report two metrics, to measure the effect of -- ecological effects of acidic deposition; one terrestrial base saturation and one aquatic, acid neutralizing capacity.

Base saturation is expressed in a percent. And it is the percent of the soil active matrix that is occupied by bases, base saturation, amount that's saturated by bases.

Those bases are the elements, calcium, magnesium and potassium, usually.

And the other possible ions that are on the soil active are hydrogen and aluminum, which are considered acid cations.

So we have sort of -- the total percentage is 100 percent. And the relative proportion that's occupied by the bases, calcium, magnesium, potassium versus the hydrogen and aluminum, provide the base saturation.

Most soils -- if we were to visit North Dakota, we would find the soils are 100 base saturated. They have all bases.

If we were to visit soils and landscapes in the southeast that have been exposed for millions of years of weathering, even without acidic deposition, their base saturations may be 10 percent or less, of the active material in the soil is saturated by bases, 10 percent or less.

Q. You also mentioned acid neutralizing capacity; what is that a measure?

A. Again, the name says it all. It is the ability of water, a sample of water to neutralize acid.

So the technique used is to add acid to the water until -- and measure until you reach neutrality, and that is the acid neutralizing capacity.

It's measured usually in terms of liters, about a quart. And it's measured by the amount of microequivalents of acid that can be used by that water.

And equivalent if you remember from Chemistry 101, is the 1 gram of hydrogen, which is the first element in the periodic table, or the amount of any other element that will replace or combine with 1 gram of hydrogen in a chemical reaction.

So one gram of hydrogen, to form nitric -- well, let's take a form -- hydrochloric acid, which is H-C-L, it takes 35 grams of chloride to react with 1 gram of hydrogen.

So one gram of hydrogen, equals one equivalent of hydrogen. 35 grams of chloride, equals one equivalent of chloride.

So it's a measure of the chemical reactivity of elements, exclusive of their weight or mass.

And microequivalent then, using the Greek prefix, is a millionth of an equivalent, not very much at all. A

millionth of an equivalent. So it microequivalents per liter is the measurement of acid neutralizing.

Q. And I'm assuming that the lower of the number of acid neutralizing capacity, that's an indicator of the inability of that body of water to neutralize more acid?

A. I believe Dr. Driscoll in his testimony spoke at some length about waters that had acid neutralizing capacity to less than 25 is, he considered to be, his term, to be sensitive, over 500, insensitive, if you want to call it that. So yes. It's a measure of the amount of acid they can neutralize.

Q. One other element in this part of the primmer I'm asking you about, I believe if you are -- your reports talk about coming up with what I call a uniformed measurement of acid deposition?

A. When I began my report, we began to look at the literature. I had tables from the North Carolina estimates of sulfur and nitrogen deposition.

And I began to essentially write parallel reports, one on sulfur and one on nitrogen and soon found it terribly redundant, and weren't reaching the direction I wanted to go.

Because I was trying to add apples and oranges, sulfur and nitrogen. But you can add apples and oranges if you convert them to a common measure.

And commonly in the acid deposition research field, a measure is again our old friend equivalents, but in this case its kiloequivalents, thousands of equivalents.

And in this case, instead of per liter, as in water, it's per hectare, a unit of land, about two and a half acres.

So the measure of acidity that can convert nitrogen and sulfur deposition to one unit is kiloequivalents per hectar.

So that's the number I used for most of my report, to be able to add apples and oranges, and focus on the acidic nature.

Q. Dr. Grigal, if I understood your response, you took some of the research materials that you used to form your opinions, and the results that they reported, and then converted those numbers to your kiloequivalent?

A. Yes I did. The report in Dr. Driscoll's -- table 9 in Dr. Driscoll's report I believe was in kilograms of sulfur and kilograms of nitrogen, and I converted that to kiloequivalents.

Q. So you have an ability, as you say, to compare apples to oranges?

A. Correct.

Q. One other question, is the question of both the variability and uncertainty -- uncertainty of measurements in natural systems and the variability of the measurement of

particular components?

A. We already, sitting in the testimony today, we've heard people mention uncertainty and variability and necessity to understand that.

And in the environmental situations, in the natural world as it were, we're a long way from the laboratory bench. And there's an extreme amount of variability out there.

Meaning, the inability to come up with the same number twice when you sample the same place and follow the same procedures.

For example, if we're looking at soil base saturation, we think of a small piece of soil out there, something the size of a backyard.

There are spots where a tree leaf or tree branch, the water drips down continuously from that branch. There's another spot where perhaps a bird did something. There's another spot where for some reason a weed grew with big luscious leaves, and those leaves fell, compared to another different spot where another variety of leaves fell.

All these things are happening in the system, are effecting the soil.

When we sample the soil at that spot and analyze it, we first have the variability that is induced in the laboratory. But then we have the variability that we almost

know for sure if we move 3 feet away, we're going to come up with a different number.

In the case of base saturation is particularly bad, we're measuring, not one number, but we're measuring calcium and magnesium separately, and potassium separately, and we're measuring the active matrix of the soil, the cation exchange capacity.

We're taking those four numbers in, each of which has its innate variability. And if you were combining them -- and don't fool yourself to think it gets less variable if you combine them, it gets even more variable.

Acid neutralizing capacity in our aquatic system is another story. Of course here we've got a nice tub of water and if we just take a sample of the water on the left side or the right side.

But that's not true in a flowing stream. Because that flowing stream changes its flow rate, perhaps on a daily, hourly basis, certainly in response to storm, response to snow melt, response to many things.

And every time the flow rate changes, the dilution changes the ANC chain.

In addition, something like a storm event will flush soil into the material matrix into the stream, also changing the ANC.

So ANC is a bouncing ball. If you were to sample the

same stream on a daily basis, you have a tremendous amount of variability.

To say that this stream has an ANC of 10 microequivalents per liter. That 10 is just sort of a number that's sort of the average of the number of times the ball's bouncing and I counted it. It wasn't the number of times I wasn't there to catch the ball and it bounced.

In other words, they're snapshots in time, a lot of noise.

Q. We will get back to the concept of noise in a moment, Dr. Grigal. When we talk about variability, is uncertainty an aspect of variability?

A. That's right. The statisticians have a trick, a statistical number trick. The more samples you take, to try to arrive at a number, obviously the better off you are.

And we measure how much variability you have in a system, by taking all the samples you have and listing them, and saying that standard deviation will contain two thirds of those samples.

Two thirds of the sample will fall within this box called the standard deviation.

There's a true value, and somewhere around that true value are two thirds of our sample.

But if we take the average of all the sample, then we've done a trick and reduced the size of that box. Now

the average still falls in a box. But instead of being a box of two thirds, it's a box of two thirds divided by the square root of the number of samples we've taken.

So if we've taken 100 samples, then we reduced the size of the box to one tenth of it's former size.

So if we have enough resources, we can take many, many samples, and reduce the size of our uncertainty, reducing the size of the box, by the square root of the number of samples we take.

Problem is that if you ever plotted numbers versus square roots, you find out that you really gain a lot with the first few samples. But when you get difference of the square root between 100, 110 or 250 or 275, there's not a lot of difference.

So you get a lot of gain at the very beginning, but very little gain after a thousand samples. Your box is still going to be there.

Q. You mentioned a concept that you called "noise"; what do you mean by that?

A. It's related to this -- the fuzz in this box. We know our sample is somewhere in this box. We know the true value is in the box. We know our sample is in the box. But we -- it's impossible to know how close we are.

Statisticians often present numbers called "confidence intervals". And they will say that, I'm sure that my number

has a 95 percent probability of being within this box that I've defined numerically. Let's say from 10 to 15, I have a 95 percent for sure -- not for sure, 95 percent certain, which means I'm 5 percent uncertain it's in that box. But I'm 95 percent certain that it's within 10 and 15, let's say.

If you want me to be 99 percent sure, I can't get the box that small. If you want me to be 99 percent sure, instead of 10 to 15, I have to go from 5 to 25.

My box size and my confidence are inversely related.

Q. What is the implications of this noise in the system when you're talking about the effects in small changes such as acid deposition or mercury deposition?

A. It's simply the fact that if the change is near the size of the noise, if you can't separate it from what you would expect to naturally occur, simply because of natural variation, then you can't measure it.

If you can't measure something, does it exist? It exists on paper. But if you can't see it or feel it or taste it, is it there?

MR. FINE: Ms. Shay, I ask you to display the document marked for identification as Defendant's Exhibit 414.

Dr. Grigal, if you would please turn to that in your book.

A. I have it. Oh, 414.
Q. 414.
A. Okay.
Q. Jumping around a little, Dr. Grigal.
A. No problem. They have numbers on them.
Q. What are we looking at here, sir?
A. When I was asked to assess the effects of delta deposition, because of the way I think, there is no way to assess the effects of delta deposition without assessing the present status of southeast systems.

And the present status of southeast systems is driven, has been changed, immeasurably, by Native American, and by European man.

One of the drivers to that change is acid deposition. Other ones are the demise of the chestnut. The current demise of the hemlock, grazing, logging.

But because we're focusing on acid deposition, I used some manipulations of numbers, statistical techniques, to derive an estimate of the total cumulative acidic deposition that's been received by sites in the southeast over the last approximately 100 years.
Q. If I can step stop just you for a moment and I apologize for the interruption.

Why the importance of cumulative deposition?
A. Just as in most chronic insults, chronic injuries --

what we're talking about here in acid deposition, is not an acute injury kind of an injury or an acute kind of injurious pollutant, or something that's been going on for a long time. And systems respond to this chronic, just as we respond to a chronic injury in our shoe by getting a blister.

It's chronic injury. So the status we are at the present, is a consequence of the history.

And so, again, in the context of acidic deposition, I attempted to estimate what is the history of acidic deposition at two sites that I chose arbitrarily out of -- I actually did it by all the sites.

I displayed Coweeta, NC-25, down near Franklin, North Carolina here, and TN-00 Walker Branch Watershed in eastern Tennessee where I worked as a post.

Q. What was your methodology, Dr. Grigal?

A. We have good data from 1980 to 2005, on emissions and on deposition at these stations.

Now, by emissions, obviously in the case of air pollutants, what goes up, must come down. The only question is, where it goes up, may not be where it comes down.

And there's a lot of talk about source areas and air sheds, and what areas.

But I took the more simple-minded approach and said, I'll take all the U.S. total emissions for sulfur and

nitrogen. I did each one separately. In this case you cannot combine apples and oranges. This summary figure does, but computation did not.

I'll take all the U.S. emissions. I don't care where they came from, whether North Carolina or Minnesota or Ohio, per year, and the precipitation at each of these stations.

Because if we're talking about acid deposition, wet deposition, than the more rain you get, chances are the more deposition you're going to get.

So I used those two variables to run regression lines to run estimates for the period of record, 1980 to 2005 -- or 2003, and found very good fits.

And then I used those relationships to extrapolate back to 1900 based on national emissions and on precipitation records at these sites, or nearby sites if I didn't have it for these sites.

Q. What is the lesson -- what is the message we should draw from this exercise?

A. We should immediately put a caveat out there, that it's unlikely that even if we have a reasonable EPA based estimate of emissions in 1900, the emission sources were somewhat different.

Instead of having large coal-fired power plants, for example, they may have been a coal-fired locomotive, or a blast furnace in Pittsburg with stacks.

So there's some difference in emission categories perhaps, there's some difference in heights of stacks, things like that.

So as we depart from 2005, heading towards 1900, there's increasing noise, increasing uncertainty.

But the one thing we are certain about is, that there's been a lot of deposition in the southeast, and indeed all over the U.S. since 1900, and in fact before 1900.

Q. What are the implications from this pattern of historic deposition in terms of looking at the impacts of the reduction of current rates of deposition?

A. Those systems that are out there, have responded to this historic pattern of deposition, in whatever way they've responded. They are not virgin systems. They have been around. And they are now poised -- not where they were in 1800 or 1850. They are poised where they are in 2008.

And any delta deposition, is not affecting some idealized case in the past. It's effecting something that's been subjected -- in the case of Walker Branch, to over 80 kiloequivalents hectare of deposition.

The delta by the way, the delta is less than .01 equivalent. Here we're talking about nearly 100 equivalents. So it's extremely small. We couldn't begin to plot it on the graph.

Q. We'll get into the implications of that a little

further in your testimony, but thank you for that.

Dr. Grigal, I believe that Dr. Driscoll testified about some core experiments that were done in the northeast?

A. Yes.

Q. Program called -- the acronym P-I-R-L-A?

A. PIRLA. I was a technical adviser on PIRLA project. Paleoecological Investigation of Recent Lake Acidification. And a critical question. Many of these questions now we take for granted.

But there really was a question of, did some of these lakes -- again, most of this research in acid deposition is not focused on the average bear, it's focused on lakes or streams or forests that people consider to be most susceptible.

It's no fun to run an experiment and get no results. So scientists are likely to run tests that get results.

In this case we went to 12 lakes in the Adirondacks. That were acid. And the question is, did they become acid naturally, or did they become acid because of acid deposition or some other impact, logging on the shoreline or whatever.

Q. Excuse me, Dr. Grigal. Let me just maybe --

A. Sure.

Q. Get this into more of the important aspects of this.

Did the findings of that study tend to support your

focus on the historic amounts of cumulative deposition?

A. The -- 8 of the 12 lakes showed a pattern of not being acid, and then becoming acid. And after they became acid, they stayed acid.

And that pattern indicated that the switchover was somewhere in the period of 1920 to 1970. But looking at their graphs, I would say 1950 was a good number.

So those lakes in the Adirondacks, if we look at my Exhibit 414, around 1950 when maybe half of what they received in the last century they received, they've already become acid.

Since then, the additional deposition has not made them any more acid. They have moved to a new stable state. They were at one state. They absorbed 40 or 50 kiloequivalents of deposition, and they kicked over to the new state and they have been at that state now for 50 or 70 years.

Q. A little off the point, but just to complete the discussion of the PIRLA results.

Were you aware of an exercise by Dr. Driscoll and some people working with him, to cut the acid levels of some of these lakes?

A. Yes. One of the projects that I was not involved in, but I read about it in the literature was a liming project, where they added lime to a couple of the lakes in the Adirondacks.

And what the lime does is, it reverses acidification. It adds bases to an acid lake. The acid neutralizing capacity is negative in an acid lake, but it quickly goes up above zero, because you have bases in there now. They were successful. They added the bases, they added the lime, the lakes became bases, they were no longer acid.

Q. Did that condition remain?

A. Unfortunately, no. In one lake about nine months, in another lake about 15 months. The lakes have already become acid all over again.

Q. And what are the implications of the acids -- the lakes becoming reacidified?

A. The rationale they presented in the paper which is reasonable, is the lakes had a relatively short residence time of water.

In other words, they were lakes, but they were sort of wide places in the stream. The water passed through them in about half a year or so, 180 days. So as soon as they started to get new water, and that new water flows, lakes and streams are not separate from any other ecosystem.

So the water that they receive flows from the atmosphere through the adjacent soil, the terrestrial system to the lake.

So once the neutral water had flushed out of the lake, it was replaced by waters that had passed through the

surrounding soil and was again acid.

Q. What's the implication of that?

A. The implication of it is, you can't expect to neutralize a lake and have it remain status quo.

You must, in fact neutralize, if you're going to neutralize the entire ecosystem that's linked to the lake.

Q. Because of the legacy of the acidification of the soils?

A. Because of the legacy.

Now to get back to Driscoll's and Jackson's testimony, they testified that these soils had been stripped of their bases in time. We have here Exhibit 414 a historical documentation of levels of deposition at that time. That stripping has left us bereft of bases. They don't just come from anywhere or everywhere. There's a very, very, very slow replacement process.

So even if we halt, later in my testimony perhaps, or in my report, we totally halt the acidic deposition, that doesn't mean the bases will return.

We will have a continuing legacy of acidic deposition, well into the next century, and centuries beyond that, in fact.

MR. FINE: Your Honor, I ask Defendant's Exhibit 414 be admitted.

THE COURT: It will be admitted.

(Defendant's Exhibit Number 414 having been marked, was received in evidence.)

Q. (Mr. Fine) Dr. Grigal and Ms. Shay, I would like to turn our attention briefly to Defendant's Exhibit marked for Identification 415.

Dr. Grigal, I believe that Dr. Driscoll testified we had, over the last 20 or 30 years, a decline in acid deposition; do you agree with that?

A. Yes. I looked at the -- both the emission inventories from the EPA and the deposition records. As I say, the deposition records were only from about 1980.

But the emission reached a peak around 1970 or '73. And certainly there has been a decline since 1980 to the present in deposition.

Q. Turning your attention to the document that's displayed on the viewer that you have in front of you and in your book marked for Identification as Defendant's Exhibit 415, what is it we're looking at here?

A. This is a table from my report. I'll go through the columns. The first two columns with the site number and the name, are the sites that Dr. Driscoll used in his expert report, to provide me with the alleged delta deposition.

They were sites in the counties in question, including Kentucky in this case, and deposition estimates.

The next column, 2002 deposition, are data that I

secured from the National Acid Deposition Program, downloaded, converted to kiloequivalents per hectare. That is the acid deposition for those two sites.

I have an average for all the sites and then an average I've chosen just the sites in North Carolina.

The next two columns are the percent of the deposition in 2002, that come from, in one case, all the TVA facilities, and in the other case, all of the anthropogenic sources in North Carolina.

These numbers were provided to me -- or the bases of these numbers. Not these numbers explicitly. But these numbers were provided to me from the TVA models. This was based on their modeling of atmospheric deposition.

And so it indicates, for example, if we look at Lilley Cornett, that about 18 percent of the deposition in 2002, originated from TVA, and about 7 percent from North Carolina.

You can see when we get to North Carolina sites, that North Carolina's a much more significant contribution to North Carolina sites than is TVA.

Finally, in the final two columns, there are two different estimates of this delta deposition that we talked about. One is the TVA estimate. That is the column labeled TVA estimate. And the other column is North Carolina estimates. Which I secured from Dr. Driscoll's expert

report.

And again, you can observe the magnitude of those, the averages for all sites, and for North Carolina. So we're looking at, based on any EPA data, North Carolina in 2002, these sites at .4 kiloequivalents per hectar of deposition. The delta, based on North Carolina estimates, is .009 as compared to 14.

Q. Can you give us the, what is the significance of that number, 0.009 kiloequivalents?

A. It would be very difficult -- difficult bordering on impossible, to see that number if you were -- if indeed it existed in the samples that you collected from North Carolina.

Because these samples are -- it's not one analysis. They're done on a weekly basis they're dependent on precipitation volume. When the precipitation varies, then deposition varies.

Even within a site on an annual, from year-to-year, there's much more variation, much more than .009. Or for all sites in North Carolina in any one year, there's much more variation than 0.09.

MR. FINE: Your Honor, I'd ask Defendant's Exhibit Number 415 be admitted into the record.

THE COURT: It will be admitted.

(Defendant's Exhibit Number 415 having been marked, was

received in evidence.)

MR. FINE: Ms. Shay, please display 413 and ask Dr. Grigal to turn back in your book to Exhibit 413.

Do you have that in front of you, sir?

A. Yes, I do.

Q. What are we looking at here, Dr. Grigal?

A. Early in my report -- I had read many reports on acidic deposition, including Dr. Driscoll's and there are terms that are bandied about, sensitive, buffering, things like that.

I thought we needed a common ground so that the readers of the report and I would know what we are talking about.

So this is a simulation on paper that a well-trained college or high school student would do was a titration.

Remember titration from high school where you drip acid from a burette into a beaker, you stir it, and you observe whether the color changes. Or in this case we monitored the change in pH.

And in this case we have 100 milliliters of sodium bicarbonate in a beaker, and we slowly add a strong acid, sulfuric acid.

And we see that we can add to the top panel 5, 10, 15, 20, 30 milliliters of acid, drops of acid, with very little change in pH.

All of a sudden we hit the tipping point where we don't

have much change, that's called a buffer. It's buffered. The system is neutralizing that acid without changing much.

Then we have a position where the system just sort of gives up the ghost, and there's a rapid drop in pH with each drop of acid.

And then again, for some reason, some good chemical reason, the system is again buffered, we keep adding acid and it doesn't add any more acid, because it's already about as acid as it can get.

So ecosystems, this is a portrayal of an ecosystem. An ecosystem is buffered against acidic deposition. It has neutralization mechanisms in it. As the acid is added, depending on the strength of the buffering, it can throw off, essentially, it can neutralize the effects of the acid, until, again depending on the strength of the buffers, it reaches a tipping point, and then it tips over, as did these lakes in the Adirondacks in 50s, and then it reaches a new equilibrium.

Sensitive systems, those at the tipping point, once they shot over the tipping point, they are no longer sensitive. They are callous. They have lost their sensitivity. They're only sensitive when they're at the tipping point.

Q. Can we reverse the effects of the addition of acid?

A. We can and we can't. We could add bases back into this

beaker. And we could force the pH back up to where we began. But the contents of the beaker wouldn't be the same. We added a bunch of sulfates to it, we've added bicarbonates. We've irreversibly altered it.

Similarly with an ecosystem, we may change the pH, but the system is never the same.

I was visiting in Garcon, in Sweden, where they did some large lake experiments to reverse acidification by liming. They reversed the acidification, but now there were multiple growths of algae that were encrusting the swimmers and stuff.

Folks that had cabins were bummed because they didn't have an acid lake any more, but they had a lake that was even worse to swim in because whatever the system had undergone, did not return it to its past state, but to a future state.

MR. FINE: Your Honor, I would ask that Defendant's Exhibit 413 be admitted into the record.

THE COURT: Let it be admitted.

(Defendant's Exhibit Number 413 having been marked, was received in evidence.)

Q. (Mr. Fine) Dr. Grigal, I believe it's reflected in your report that you made some efforts to quantify the ecological effects of changes in deposition?

A. I did.

Q. And we have the benefit, of course, of your reports in the record. If you could briefly describe for us the steps you took to try and quantify the ecological effects and changes in deposition?

A. There is very little data that attempt to quantify or to quantify the impacts. And I scoured the literature and there are three approaches that I used to try to put numbers on the impacts.

One was modeling approaches. Two was direct experiments, large scale experiments. And the third was, let's call it an even larger experiment, a happenstance based on the reductions in emissions that occurred over the last 30 or 40 years.

In more detail, SAMI which we folks heard about here in court, a lot, had a modeling component that modeled both responses of streams, and responses of soil to their changes in emissions which were translated to changes in deposition.

Q. And what did the SAMI molding showed?

A. It showed, in fact, increasing loss of base saturation, a slight increase in acid neutralizing capacity, with very, very large changes in deposition.

So that what I did was, I normalized the numbers to changes in, let's say, base saturation per kiloequivalent of change in deposition -- or changes in acid neutralizing capacity per kiloequivalent. And on that bases they showed

some quite low numbers.

For example, each change in a kiloequivalent of deposition, will lead to a less than a five hundredths percent change in base saturation soil, and less than a half of microequivalent per liter of acid neutralizing capacity. That was based on SAMI.

Q. How were those numbers of the change in deposition, compare to the delta deposition that you were looking at in this case?

A. We're looking at, as I said earlier, .009. So we're talking about numbers that are -- how do I say it -- they are -- to achieve measurable changes in base saturation, or acid neutralizing capacity -- we take hundreds, in the case of acid neutralizing capacity for thousands of years at the rate of delta -- in case of base saturation, if delta deposition was operative at these rates that SAMI's models indicated.

Q. I believe you also looked at some modeling that was actually performed using the model that Dr. Driscoll was involved in, the PnET-BGC?

A. Yes. Dr. Driscoll and his graduate students worked in the northeast, not in the southeast. But I grab data where ever I can find them.

And worked in three or four different studies where they applied PnET-BGC, again with some quite sharp emission

reductions, leading to deposition reductions. And again they were reflected in changes in base saturation and in ANC.

And if I normalize them to the same unit of measure, change in base saturation per kiloequivalent, or change in ANC per kiloequivalent, I find results that are harkeningly similar to SAMI numbers.

SAMI was .04 for base saturation. PnET-BGC was .1. About twice as much. But very small numbers.

ANC for SAMI was .5. For PnET-BGC was .6 microequivalents per liter per kiloequivalent. So very similar. And the time then would be very similar, thousands of years to get a measurable change in base saturation; hundreds of years to get a measurable change in ANC.

Q. Based on the alleged delta deposition --

A. Based on the alleged delta deposition and the results of these -- both of these modeling exercises.

Q. I think you also mentioned a series of experiments?

A. There were some experiments -- whole experiments are big and difficult to carry out, and expensive.

And the problem with most experiments in this area is, they added more acid to an already acidified system. We just looked at my Exhibit 414. So now what these folks have done is added even more acid, to see if they could get a bigger response. And of course they didn't add a little bit

of acid. Because the funding agency would say, well, you better find something in 10 years or else.

So they doubled and tripled the current deposition, of these already presumably impaired systems. But I'm not blaming them. That's all they could do.

But see in Norway, they did something different. In the U.S. and at Pherno (phonetic spelling) in West Virginia, and at Bear Brook, which is up in Maine. They had experiments where they added acidifying substances -- actually fertilizer, amonium sulfate -- but it acts just as acid deposition does.

And they monitored them for about a decade a piece, the response of the streams, and attempted to monitor response to the soils, to the added insult of the additional deposition.

Q. And what result did they achieve from the -- assuming the amounts they added were substantially in excess of the alleged delta deposition we're looking at in this case?

A. Remember my graph peaked at around 80 kiloequivalents, or something like that, historically.

Well they added -- in Pherno they added over 5 more kiloequivalents in a 10 year period. They really socked it to it, compared to the delta deposition .009, .009 versus 5.

And, as you may expect, the ANC went down in the streams because they added more acid.

Q. Went up?

A. No it went down. It continued to go down. It went down at a faster rate than their control watershed. The control watershed was next door. It also went down in the control watershed. But in the acidified watershed it went down even faster. And they could not detect a change in base soil saturation, in Knoll.

In Bear Brook they detected a change, but it wasn't really valid, because they didn't sample before they experimented, they only sampled after. And then they decided what it must have been before, if this is what it was after. So it was an unsatisfying measurement of soil base saturation.

But again, I converted those numbers to the changes in kiloequivalents, base saturation and/or acid neutralizing capacity.

And maybe surprising, maybe not, the numbers were very similar to the modeling results. That is the change in acid neutralizing capacity per added kiloequivalent was very similar to what the modelers predicted the change would be per in kiloequivalent.

But in the case of base saturation, as I said, in Knoll they didn't find any change. It was a wash.

Q. I think you mentioned an experiment in Norway called RAIN?

A. RAIN was attempt to exclude acid rain, to really do what I said, to exclude it. But they had to do it on a very small area, less than a quarter of an acre.

It was a landscape in Norway, which almost looks like this table top, a little patch of soil here, a little patch there, mainly granite bedrock.

Q. You visited the site?

A. I visited it. With little gnarly trees, you know, half the height of a person.

And they put an umbrella over the whole watershed, and captured all the water that they could, neutralized it, and sprayed it back on.

And then in an adjacent sandbox watershed, they did the same thing. But in this case they didn't neutralize it, the just sprayed it back on to the watershed. And they looked at the difference then, what happened.

And with this, virtually 100 percent drop in acid deposition, they could find no change in soil base saturation. They searched and searched. Every year they sampled the soil. Some years it was up, some years it was down, variability.

They did find, however, that the ANC of the stream began to go upward. That is, it became -- it never did reach neutrality, never did hit zero. It was always negative. But in the eight year period it continued to

rise.

And again when I divide it through by kiloequivalents, microequivalents of stream change per kiloequivalent. In this case the numbers were much larger than our experiences at, for knoll or Bear Brook or our modeling results.

And I ascribed -- they were about 8 microequivalents per liter per kiloequivalent.

Still not enough to make the stream basic, but at least it was -- it was nearly a measurable change.

And I ascribed this to the fact that it was almost a laboratory experiment, almost a tabletop experiment. If they couldn't get a result there, no one could.

Q. I think you mentioned that there's been some study of actual -- response to the actual emissions reductions in natural areas?

A. There were three studies again, primarily in the northeast. Based on the fact that emissions and therefore deposition, has declined since about 1970 or '75. We don't really know, but certainly since measured in 1980 it has.

So these folks sampled the lakes over a decade or multiple -- a couple decade period, to determine the change in the ANC in these lakes, based on the change in deposition that had occurred, as a result of the Clear Air Act and other things.

And they did not sample soil at all. They did find

changes in ANC that were somewhat similar to the RAIN changes, in terms of amount per kiloequivalent, which sort of surprised me, at first. But then I also decided that maybe their change was exaggerated, simply because they were looking at a change over a decade period in water quality. But that was really reflecting the change in deposition since 1970 or '73.

So we had a 30 year change in deposition. And they were only looking at a short change. And so if I thought, well really, the change that's effecting these lakes during this decade-long period, because of the lag effect, because it takes a while to get the system changed, is really the effect of the change in deposition over the whole period, that is since about 1970, then the numbers came up more similar to those of modeling and Bear Brook and things.

But in any event, the numbers still weren't large. They were about range size numbers.

Q. Dr. Grigal, I believe that you know that Dr. Driscoll talked about a concept of critical load?

A. I do.

Q. And are you familiar with that concept?

A. In 19 -- I should look at my reference list here. But in -- early on in 1990, though I did the research in '89 and '90, I wrote a paper critically examining critical loads.

Q. What is your assessment of that concept?

A. Well critical loads are a concept that decides that there's a threshold, there's some kind of a magic number, above which you are safe, below which you are lost.

And as we just looked at by historical record, we have a chronic system here. It seems ridiculous to somehow in this step-wise increase in cumulative deposition, all of a sudden to say, well, from now on, if we don't get any more than 5 or something, all will be well.

It tries to assume from an acute threshold mentality, on a chronic kind of a injury to a system.

In addition, critical loads, as Dr. Driscoll espouses, finds the most critical element in the ecosystem.

So Dr. Driscoll mentioned that his picture of the Smokies showed the diverse landscape.

Well, each member of that landscape has a different critical load, depending on how you determine critical load, which is a whole other maelstrom of questions.

But each point of the landscape would have a different critical load. The objective being to find the minimum critical load, and apply that to the whole ecosystem.

We just heard about risk analysis. Risk analysis says, there may be some sacrifices that have to be done because of social, economic or other factors.

And -- so critical loads is -- seems -- seems simple. And unfortunately most things that seem simple, are too

simple. If it sounds too good to be true, it is too good to be true.

Q. Are there any uncertainties in determining the amount of critical loads?

A. Well, that's what I said. There's a whole maelstrom of trying to assess impacts.

For example, one of the critical loads deals with nitrogen. There's a hypothesis in the literature that if an ecosystem is leaking nitrogen, if nitrogen is coming out of an ecosystem, it's saturated, it can't hold any more, it's reached its critical point.

At Pherno, they added, to a leaking ecosystem, they added 500 pounds of nitrogen per acre. 90 percent of it was retained by the ecosystem.

Even though when they started it was already leaking. Theory would say if they added 500 pounds it would slush out the tube. 90 percent of it was retained.

They can't explain it. But it does cast some aspersions on some of our hypotheses that are used as the bases for critical loads.

Q. Dr. Grigal, one other area I would like to get into in the area of acid deposition is, if you could -- I think you already alluded to this already briefly. But how long would it take to see the effects of the alleged delta deposition in terms of measurable impacts on the ecosystem?

A. If we take all the studies that I mentioned, and just take their average. Even if the RAIN was higher than SAMI, it would take to reach about 5 percent base saturation, a change of 5 percent which may be measurable, it would take about 2,000 years of the alleged delta deposition.

And in terms of reaching the acid neutralizing capacity of 10 microequivalents per liter, which is barely what a good laboratory could do, in two samples that are taken at the same time, it would take about 200 years for the alleged delta deposition to even be measurable in terms of response to a stream.

My question -- my philosophical question is, what is the future going to be like in 200 years, or 100 years, or 50 years, in terms of these streams?

We're not in steady state by any means. And my divisions and extrapolations assume a steady state, everything is going to stay the same. But 200 years for streams, 2,000 years for soil.

MR. FINE: Your Honor, with some regret, I would note the time of day, and the fact that we're about to move -- I'm about to move into, with Dr. Grigal, to the question of mercury deposition. Which will unfortunately, sir, take some time. Plus whatever time worthy opposing counsel needs for cross.

We will of course abide by how His Honor wishes to

proceed. I regret this as much as anyone, since we're looking at, as I understand it, a long weekend. I'm also consciousness of the fact that we have been at this for quite some time, as has the Court.

THE COURT: Are you posing that we continue this after the weekend?

MR. FINE: Your Honor, in all candor, that may be the best course of action. As personally painful as it may be to a number of us is in the courtroom.

THE COURT: What about you?

THE WITNESS: Personally painful to me, sir. I have a three-day weekend in a lonely motel room in Asheville, but I can do it. I can do it. I'm a soldier, and I will march on.

THE COURT: All right. If you're willing to do that.

THE WITNESS: Not eager, but willing.

THE COURT: Okay. Then I accept that as an alternative to another couple of hours.

All right. Then let's take a recess until Tuesday morning at 9:00.

(End of Proceedings.)

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UNITED STATES DISTRICT COURT
WESTERN DISTRICT OF NORTH CAROLINA

CERTIFICATE OF REPORTER

I, Laura Andersen, Official Court Reporter, certify that the foregoing transcript is a true and correct transcript of the proceedings taken and transcribed by me.

Dated this the 29th day of July, 2008.

s/Laura Andersen
Laura Andersen, RMR
Official Court Reporter